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MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

VOLUME XXVI (1940)

CONTAINING PAPERS SUBMITTED AT THE ANNUAL MEETING IN 1940

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PART I: BOTANY AND FORESTRY

PART II: ZOOLOGY

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Anthropology, Economics
Language and Literature

PAPERS OF THE MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

EDITORS

EUGENE S. McCARTNEY

MISCHA TITIEV

VOLUME XXVI (1940)

"Pusilla res mundus est nisi in illo
quod quaerat omnis mundus habeat."
— SENECA, *Naturales Quaestiones*

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BOTANY

NOTES ON THE MICHIGAN FLORA. VIII

OLIVER A. FARWELL

THIS paper records the finding of plants that are new to Michigan and contains notes on rare or interesting species. Of the counties mentioned, Keweenaw and Houghton are in the north-central part of the Upper Peninsula; the others are some 450 miles farther south, in the southern part of the Lower Peninsula.

List of Species

OSMUNDA CINNAMOMEA Linn. var. **sterilis,** var. nov. — Cinnamon fern. *Lamina supra sterili, infra fertili.* The fertile frond is more or less sterile, the fertile part occurring below, the sterile above; some of these sterile pinnules are crowded, more or less crisped, plaited or pinnatifid. Presumably similar to var. *frondosa* A. Gr., but in that variety the fertile part is uppermost, just the reverse of the arrangement here. Romulus, Wayne Co., no. 8674, June 3, 1930. Rare.

OPHIOGLOSSUM VULGATUM Linn. — Adder's tongue. The only time I have seen this plant in the field in forty years of botanizing in the Lower Peninsula. Romulus, Wayne Co., no. 8673, June 3, 1930.

HIPPOCHAETE LAEVIGATA (A. Br.) O. A. F. var. RAMOSA (A. A. E.) O. A. F. — The fertile stem sends out sterile branches at the base of the nodes in the upper half, or sometimes from near the base of the stem throughout. Algonac, St. Clair Co., no. 3685, June 21, 1914. Flat Rock, Wayne Co., no. 7946, June 8, 1927. Farmington, Oakland Co., no. 8625½, Oct. 8, 1929.

PICEA BREVIFOLIA Peck. — Swamp spruce. As found on the Keweenaw Peninsula the swamp spruce is a dwarf tree rarely over ten feet high and growing only in peat bogs; fruit is seldom produced. It is readily recognized by its short, glaucous leaves. Keweenaw Co.: Cliff Mine, no. 42a, Aug., 1900; Eagle Harbor, no. 11732, June 27, 1938. Laurium, Houghton Co., no. 11496, Aug. 14, 1936.

JUNIPERUS COMMUNIS Linn. — Common juniper. The typical variety of the species, which is a tree; this is the only place I have seen it in Michigan. Tyrone, Livingston Co., no. 8677, June 10, 1930.

POTAMOGETON MICROSTACHYS Wolfg. (*P. alpinus* Balbis). — Fernald has recently shown that this name should replace *P. alpinus*. St. Clair River at Marine City, no. 6751, Aug. 29, 1923. Detroit River, no. 514a, Sept. 30, 1892.

Var. SUBELLIPTICUS Fernald. — Streams on the Keweenaw Peninsula, no. 514, Aug. 1, 1887.

ECHINOCHLOA CRUSGALLI (L.) Beauv. f. **zelayensis** (HBK.), comb. nov. (*Oplismenus zelayensis* HBK., *Nov. Gen. et Sp.*, 1 : 108. 1815). — Very similar to f. *mitis* (Ph.) O. A. F., from which it is difficult satisfactorily to distinguish it. Detroit, Wayne Co., no. 648a, Aug. 18, 1893. Oakland Co.: Orion, no. 648c, Aug. 29, 1895; Avon, no. 6850, Oct. 3, 1923. Marquette, Marquette Co., no. 648d, Aug., 1902.

PANICUM DICHOTOMIFLORUM Mx. var. GENICULATUM (Muhl.) Fern. — Although Fernald (*Rhodora*, 38 : 387–390. 1936) claims that *P. geniculatum* Muhl. (*Muhl. Cat.*, p. 8. 1813) is only a substitute name for *P. dichotomiflorum* Mx. (*Fl. Bor. Am.*, 1 : 48. 1903), yet the evidence he produces clearly shows otherwise, and indicates that it is a legitimate renaming of Walter's plant *P. milliaceum*? (*Fl. Carol.*, p. 72. 1788), which Walter had wrongly identified. Muhlenberg not only gave Walter's habitat and excluded that of Michaux's species, but also took his specific name from the description by Walter. Therefore Muhlenberg's species *must rest upon the description that gave rise to the specific name.* If Muhlenberg included both Walter's and Michaux's species in his *P. geniculatum* it merely shows that he did not differentiate between the species of Michaux and of Walter but that Walter's species giving rise to Muhlenberg's specific name *must stand as its type.* Furthermore, Fernald admits that Muhlenberg described the same plant as did Walter. Fernald's conclusions, nomenclatorily, are contrary to the facts. He attributes the varietal name *geniculatum* to Wood. That Wood was not familiar with the publications of Muhlenberg and of Elliot and that he did not get his varietal name *geniculatum* from them, even if he did not say so, is unthinkable. "Muhlenberg" should be the name enclosed in marks of parenthesis instead of "Wood." This variety is the only

form of the species that I have found in Michigan. Detroit, Wayne Co., no. 4101, Sept. 23, 1915, no. 4812, Nov. 15, 1917, and no. 11697, Sept. 9, 1937. Oxford, Oakland Co., no. 6416, Oct. 4, 1922. Lake Linden, Houghton Co., no. 12247, Oct. 6, 1939.

PANICUM STRICTUM Ph. var. **psilophyllum** (Fern.), comb. nov. (*P. depauperatum* Muhl. var. *psilophyllum* Fern., *Rhodora*, 23: 193. 1921). — Frequent throughout Michigan. St. Clair Co.: Port Huron, no. 4970, June 20, 1918; Algonac, no. 5498, June 20, 1920. Portage Lake region, Washtenaw Co., no. 5850, June 12, 1921. Seven-Mile Point, Keweenaw Co., no. 11338, July 16, 1936.

PANICUM LANUGINOSUM Ell. var. FASCICULATUM (Torr.) Fern. subvar. **pilosum** (Torr.), comb. nov. (*P. nitidum* var. *pilosum* Torr., *Fl. N. and Mid. U. S.*, p. 148. 1824). — The variety and subvariety intergrade, and both are common throughout the state.

PANICUM LANUGINOSUM Ell. var. IMPLICATUM (Scribn.) Fern. subvar. **meridionale** (Ashe), comb. nov. (*P. meridionale* Ashe, *Journ. Elisha Mitchell Sci. Soc.*, 15: 59. 1898). — The subvariety is less pubescent than the variety. Both are found throughout the state.

CHAETOCHLOA GLAUCA (L.) Scribn. var. **purpurea,** var. nov.[1] — *Setis purpureis.* Bristles purple. Widely distributed in southeastern Michigan. Wayne Co.: Detroit, no. 5661, Sept. 1, 1920, and no. 6467, Oct. 28, 1922; Redford, no. 7246, Oct. 8, 1924. La Salle, Monroe Co., no. 7167, Sept. 17, 1924. Bloomfield, Oakland Co., no. 7278, Oct. 19, 1924.

AGROSTIS SYLVATICA Huds. — Very good specimens were found, one in low swampy ground and the other in dry stamp sand. It is apparently a pathological form of *A. stolonifera* L. (*A. vulgaris* With.). Keweenaw Co.: Eagle Harbor, no. 11749, June 27, 1938; Cliff Mine, no. 12119, Aug. 26, 1939.

AMMOPHILA BREVILIGULATA Fernald. — Beal gives no citation for the Upper Peninsula in his *Michigan Flora.* Found on sand dunes and sand shores. Keweenaw Co.: Bete Grise Bay sands, no. 9287, Sept. 1, 1932; Sand Bay dunes, no. 11816, Aug. 29, 1938.

[1] CHAETOCHLOA GENICULATA (Lam.) Millsp. and Chase var. **purpurascens** (Ell.), comb. nov. (*Panicum glaucum* L. var. *purpurascens* Ell., *Bot. S. C. and Ga.*, 1: 113. 1816). — In my herbarium is a sheet of this variety, the label for which has been lost. The spike is slender and has short, purple bristles. It probably came from South Carolina; it is not a Michigan plant.

TRISETUM SPICATUM (L.) Richter. — Downy oat grass. The downy oat grass is found on rocky shores of Lake Superior. Keweenaw Co.: Hunter's Point, no. 11302, July 14, 1936; Hebard Park, no. 12003, July 31, 1939. Lake Linden, Houghton Co., no. 1825½, Aug., 1904.

Var. MOLLE (Mx.) Beal. — On rocky shores of Lake Superior. I have not found the variety growing in association with the species, but intermediate forms occur. Keweenaw Co.: Copper Harbor, no. 658, Aug. 16, 1888, and no. 4004½, July 8, 1915; Eagle Harbor, no. 10027, Sept. 17, 1934.

POA INTERIOR Rydb. — Forms dense caespitose clumps or stools. In sand at Agate Harbor, Keweenaw Co., no. 11642, June 27, 1937. The only place I have seen it in Michigan.

POA NEMORALIS Linn. — Very similar to *P. interior* Rydb. Not at all frequent. Usually in rocky fields or woods. Keweenaw Co.: Cliff Mine, no. 848½, June 27, 1895; Copper Harbor, no. 850½, July 1, 1895. Bloomfield Center, Oakland Co., no. 4995, June 29, 1918.

GLYCERIA FERNALDII St. Johns. — A low procumbent grass in wet grounds near Laurium, Houghton Co., no. 11664, July 21, 1937. F. J. Hermann first found it here in 1936.

Fernald has presented revisions of *Festuca rubra* L. (*Rhodora*, 35:132–133. 1933) and *F. ovina* L. and its allies (*Rhodora*, 37:250–252. 1935). According to these revisions we have in Michigan the following varieties:

FESTUCA RUBRA Linn. — Found only once. Detroit, Wayne Co., no. 4509, July 6, 1917.

Var. COMMUTATA Gaud.[2] — Rochester, Oakland Co., no. 4504, June 28, 1917.

Var. SUBVILLOSA Mert. & Koch. — Ypsilanti, Washtenaw Co., no. 5746, May 19, 1921.

FESTUCA OVINA L. — The typical variety of this species; Fernald restricts it to the range "Quebec to western New York and New Jersey."[3] It is found throughout Michigan. Cliff Mine, Keweenaw Co., no. 793, Aug. 18, 1890. Wayne Co.: Detroit, no. 793a, June 24, 1902, and no. 2020½, June 6, 1907; Livonia, no. 9407,

[2] Collected at Pocono, Pa., no. 8913, June 29, 1931.
[3] Collected at Pocono, Pa., no. 8914, June 29, 1931.

June 7, 1933. Ypsilanti, Washtenaw Co., no. 5747, May 15, 1921. Birmingham, Oakland Co., no. 8882, June 9, 1931.

Var. HISPIDULA Hackel. — In this variety the glumes and lemmas are hispid and bristly ciliate on the upper parts. Rochester, Oakland Co., no. 1722, July 4, 1901.

FESTUCA DURIUSCULA L. — Fernald regards this as a variety of *F. ovina* but it appears to be as distinct as *F. occidentalis* Hk. Its measurements should be increased as follows: height up to three and one-half feet; length of panicle up to nine inches and breadth of leaves up to one line. Trap Rock Valley, Houghton Co., no. 11727, June 19, 1938. Hebard Park, Keweenaw Co., no. 12005, July 21, 1939.

Var. **pubiculmis** (Hackel), comb. nov. (*Festuca ovina* L. var. *pubiculmis* Hackel). — In this variety at least the upper half of the culm is puberulent, and the panicle axis and branches are bristly. Algonac, St. Clair Co., no. 3641, May 24, 1914.

FESTUCA SAXIMONTANA Rydb. — This segregate of *F. ovina* is abundant on rocky shores and bluffs and may be found up to eighteen inches in height. Keweenaw Co.: Hunter's Point, no. 11303, July 14, 1936; West Bluff, no. 11315, July 14, 1936.

FESTUCA OCCIDENTALIS Hk. — This species is abundant in Keweenaw Co. in rocky woods and on rocky shores. It reaches a height of three and three-quarters feet, with a panicle often nine inches long. The stems are usually green but are sometimes red. Keweenaw Co.: Cliff Mine, no. 531, Aug. 5, 1887, and no. 531a, June 27, 1895; Copper Harbor, no. 849¼, July 1, 1895, no. 8493, July 24, 1929, and no. 8496 (red stems), July 24, 1929; Mt. Brockway, no. 10944, July 25, 1935; Hunter's Point, nos. 11270 and 11270a, July 14, 1936; near Lake Glazon, no. 11802, Aug. 29, 1938.

CLAUDIUM MARISCOIDES (Muhl.) Torr. — Twig rush. Beal gives this species for the Lower Peninsula only. I believe this is the first record for the Upper Peninsula. Houghton Co.: Rice Lake, southeast shore, no. 12048, July 28, 1939, and northwest shore, no. 12123, Aug. 30, 1939.

SCIRPUS CAESPITOSUS Linn. var. CALLOSUS Fernald. — Club rush. As I walked through a peat bog near Eagle Harbor my toes were continually catching underneath culms that were bent over and

rooting at the tip. *Eleocharis rostellata* Torr., I concluded. I collected some fruiting culms and reported the plant under that name, observing at the time that its spikes seemed rather small and more or less abortive; but I gave it no further study then. Recently the specimens again came under my observation, and I immediately saw that something was wrong. A close examination revealed that they were *S. caespitosus*. *E. rostellata* was probably there, but I failed to get any of it, even of the sterile culms rooting at the tip. Keweenaw Co.: in peat bogs at Eagle Harbor, no. 6631, June 29, 1923, and nos. 10008 and 10040, July 17, 1934; on rocky shores at Hunter's Point near Copper Harbor in dense, tough, caespitose clumps, no. 11276, July 14, 1936.

CAREX ARCTA Boott. — Beal gives only one location in Michigan, that of my early collection in Keweenaw Co. I have the species now from Houghton Co. Borders of Black Pool, northwest of Cliff Mine, Keweenaw Co., no. 624, July 26, 1888. In low wet grounds near Jacobsville, Houghton Co., no. 12147, Aug. 30, 1939.

CAREX PENNSYLVANICA Lam. var. **livoniensis**, var. nov. — *Planta dioica.* Plant dioecious. In moist woods at Livonia, Wayne Co., no. 9368, April 25, 1933.

CAREX PRASINA Wahl. — Sedge. In swampy grounds in valleys. Livonia, Wayne Co., no. 9454, July 18, 1933.

XYRIS MONTANA H. Ries. — Yellow-eyed grass. Beal gives no collections or collectors, merely citing it from *Gray's Manual*, Revised Edition, as a Michigan plant. Houghton Co.: shores of Lake Roland, no. 10253, Aug. 15, 1934; Rice Lake, southeast shore, no. 12042, July 28, 1939, and northwest shore, no. 12132, Aug. 30, 1939.

TRADESCANTIA REFLEXA Raf. var. **eloiseana**, var. nov. — *Flore majore, 1.5 uncias in diam., petala obtusa, ovata, unam unciam longa.* Flowers larger, one and one-half inches across; petals broadly ovate, obtuse, one inch long, from royal purple to dark violet (Ridgway, 1912). The flowers are much larger and darker than the ordinary bluish purple (blue-violet, Ridgway, 1912) flowers of the typical variation of the species. Eloise, Wayne Co., no. 8902, June 16, 1931.

JUNCUS GERARDI Lois. — Black grass. In wet ditches. This is the first time it has been observed or collected in Michigan, in so far

as I am aware. Beal includes it in his *Michigan Flora*, not on specimens collected in Michigan, but on the basis of the following statement in *Gray's Manual*, Revised Edition: "Rare about the Great Lakes." The stem leaves number, actually, seven; the first three, at the base of the stem, are short-bladed and inconspicuous, but the next four are long-bladed and prominent, covering the stem nearly up to the inflorescence. Wayne, Wayne Co., no. 8897, June 16, 1931.

JUNCUS TENUIS Willd. var. ANTHELATUS Wieg. — This variety is infrequent. Moist ravines. Lake Linden, Houghton Co., no. 11788, Aug. 21, 1938.

JUNCUS BOGOTENSIS HBK. var. **decipiens** (Buchn.), comb. nov. (*J. effusus* var. *decipiens* Buchn., *Engl. Bot. Jahrb.*, 12:229. 1890). — This variety is very scarce on the Keweenaw Peninsula. On the southeast shore of Rice Lake, Houghton Co., no. 12052, July 28, 1939. On the sandy shore of Bete Grise Bay, Keweenaw Co., no. 12110, Aug. 16, 1939.

ALLIUM SIBIRICUM L. — Chives. At an early date this was reported as *A. Schoenoprasum* from Eagle Harbor, Keweenaw Co. (no. 463, Aug. 30, 1886). Recently it has been found again in ravines. Lake Linden, Houghton Co., no. 11728, June 26, 1938.

IRIS PSEUDACORUS Linn. — Yellow iris or flag. In several inches of water on the shores of Middle River Rouge, where there is a clump with a dozen or more stalks four or five feet high. Northville, Wayne Co., no. 9116, June 22, 1932. Rare.

CORALLORRHIZA TRIFIDA Chat. var. **virescens** (Farr.), comb. nov. (*C. innata* var. *virescens* Farr.). — The flowers are yellowish green. Collected near Silver Mountain, Houghton Co., June 10, 1939, by Walter Mattson.

BETULA ALBA L. — Canoe birch, paper birch. The typical variety of this species is frequent on the Keweenaw Peninsula, and the var. *papyrifera* (Marshal) Spach, which is cut for firewood, is very abundant. The typical species has been collected as follows: Houghton Co.: Lake Linden, no. 11576, Sept. 24, 1936; on the shores of Little Traverse Bay, no. 12039, July 28, 1939.

Var. CORDIFOLIA (Regel) Fernald. — This variety is scarce. Its leaves are cordate. West Bluff, Keweenaw Co., no. 12154, Sept. 5, 1939.

POLYGONUM CONVOLVULUS L. var. **erectum**, var. nov. — *Planta*

minima erecta. Differs from the species only in being small and erect, under a foot in height. In waste grounds and on sand. Lake Linden, Houghton Co., no. 10115, July 28, 1934.

Polygonum cilinode Mx. var. erectum Peck. — On rocky grounds but not so abundant as the species type, which is plentiful even in swampy grounds, where it climbs over alders. Vicinity of Lake Glazon, Keweenaw Co., no. 12012, July 21, 1939. Houghton Co.: vicinity of Hungarian Falls, no. 10425, Aug. 30, 1934; Calumet, no. 11781, July 29, 1938.

Polygonum articulatum Linn. — Beach jointweed. Frequent in shore sand at Bete Grise Bay, Keweenaw Co., no. 9288, Sept. 1, 1932.

Kochia scoparia (Linn.) Schrad. — Summer cypress. River Rouge, Wayne Co., no. 9308, Sept. 14, 1932. Quite abundant. At this place and time we also observed var. *tricophylla* (Voss) Moellen. It has narrower, linear leaves, and the whole plant turns red in autumn. It is known as Mexican fire plant and is well established in southeast Michigan. The oldest varietal name is *culta*, and the variety should be known as *K. scoparia* (Linn.) Schrad. var. **culta** (Voss), comb. nov. (*Bassia scoparia* var. *culta* Voss). This variety was also found at Oakwood, now a part of Detroit, Wayne Co., no. 8811, Sept. 30, 1930.

Stellaria media (Linn.) Cyr. var. maxima (Schur) Guerke. — Chickweed. This species is very variable and may be found in all situations from rich garden soil to rocky or sandy hills and in rich woods; it is equally at home among native plants in primeval places and among naturalized weeds in cultivated grounds. Usually rated as an introduction, but I have no doubt that it is also native. Wayne Co.: Livonia, no. 8713, July 8, 1930; Northville, no. 9094, June 15, 1932.

Thalictrum dioicum Linn. — This is an early spring plant with greenish flowers, found on hillsides in copses, etc. Ypsilanti, Washtenaw Co., no. 1125, May 29, 1891. Belle Isle, in Detroit River, no. 1125a, June 20, 1893. Rochester, Oakland Co., no. 3626, May 17, 1914.

Thalictrum Cornuti Linn. (*T. canadense* Mill.; *T. confertum* Moench.; *T. corynellum* DC.; *T. polygamum* T. and G., not Muhl.). — As has been pointed out by the late E. L. Greene, there never was any real excuse for dropping the early Linnaean

name for one of much later date (not even the next in order and misapplied in the bargain). Beal included the species in his *Michigan Flora* as from the Keweenaw Peninsula on the strength of my early collection. I now find it for a second time, 450 miles to the south of the original station. Wayne, Wayne Co., no. 8900, June 6, 1931; original station, Cliff Mine, Keweenaw Co., no. 133, July 10, 1884. A new variety is recorded from New York.[4]

Thalictrum Cornuti Linn. is based on *T. canadense* Cornut, a species derived solely from Canada; *T. rugosa* Ait. is based on a North American specimen sent to Europe by Fothergill in 1774. Willdenow merely reproduced the description of Aiton; Pursh used Aiton's description but added to it. These names should be retained for the American species to which they were originally applied and should not be rejected in favor of the names of European species which in some way not now determinable were substituted for them.

Thalictrum purpurascens Linn. — Stem and flowers purplish; leaflet usually three-toothed, thin, oblong or lanceolate; margin even, puberulent beneath, *not glandular; inflorescence and fruit glabrous;* filaments filiform or slightly clavate, drooping in anthesis. Usually on low moist grounds. Cliff Mine, Keweenaw Co., no. 132, July 10, 1884. Ypsilanti, Washtenaw Co., no. 132a, June 23, 1891. Belle Isle in Detroit River, no. 132b, July 21, 1892. Parkedale, Oakland Co., no. 2781, June 30, 1912, and no. 3703, June 28, 1914. (I also have this from Peeks of Otter, Bedford Co., Va., collected by A. H. Curtiss in June, at an elevation of 4,000 ft. H. H. Rusby's no. 502, June, 1883, from Oak Creek, Ariz., is the same.)

Var. **rugosum** (Ait.), comb. nov. (*Thalictrum rugosum* Ait., Willd., Pursh; *T. carolinianum* Bosc. ex DC.; *T. dasycarpum* Fisch., Mey., and Ave-Lall.). — Similar, but it has *sparsely pubescent nonglandular fruit,* the ribs of which are sometimes branching. Belle Isle, in Detroit River, no. 1384a, June 27, 1893. Parkedale, Oakland Co., no. 3704, June 28, 1914. Detroit,

[4] Var. **stipitum,** var. nov. — *Fructu stipitato pubescenti.* In this variety the achenes are conspicuously stalked and beset with a few scattered hairs. Elmira, Chemung Co., N. Y., T. F. Lucy, no. 227, July 2, 1896. The range of this long-stipitate variety is said to be from New York to the Carolinas.

Wayne Co., George Suttie, June 6, 1891. (A. L. Johnson, Walkerville, Ont., June 1, 1892.)

Var. CERIFERUM C. F. Austin. (*Thalictrum pubescens* Ph.; *T. revolutum* DC.; *T. polygamum* Muhl., not T. and G., Sprengel). — Leaves thicker, margin revolute, underside puberulent *and glandular;* fruit pubescent, often glandular; glands sessile or stipitate. Cliff Mine, Keweenaw Co., no. 751, July 12, 1890. Detroit, Wayne Co., no. 1504a, June 9, 1896. (Also in the herbarium of Parke, Davis and Co., from Montclair, N. J., H. H. Rusby, no. 25A, July, 1879.)

JEFFERSONIA DIPHYLLA (Linn.) Pers. — Twin-leaf or rheumatism root. This rare member of the barberry family was found in Oakland Co. by Bach and Gladewitz in 1916. Livonia, Wayne Co., no. 9362, April 25 and May 17, 1933. Livonia is the only known station in Wayne County, and the plant is scarce; probably less than twenty individuals were observed.

BERBERIS THUNBERGII DC. — Japanese barberry. This is quite well and extensively established in rich woods in Rochester. The shrubs are over six feet high and fruit-bearing. Rochester, Oakland Co., no. 8729, Aug. 13, 1930.

SANGUINARIA CANADENSIS Linn. — Bloodroot. This is our most frequent species of bloodroot in southeast Michigan.

F. **incarnata,** f. nov. —*A specie incarnatis petalis differt.* Petals pink or flesh-colored, six to eleven lines long by two to four lines wide; flowers circular in outline. Melvindale, Wayne Co., no. 9377, May 2, and fruit May 23, 1931.

SANGUINARIA DILLENIANA Greene. — The flowers are quadrangular, of from seven to nine petals in two sizes and shapes; four large petals ovate, about fourteen lines long by seven or eight wide; smaller petals oblanceolate, about twelve lines long by three or four wide. Spread of flower when flattened out about two inches. Livonia, Wayne Co., no. 9363, April 25, and fruit May 17, 1931.

ARABIS LYRATA Linn. f. PARVISILIQUA Hopkins. — Washington, Macomb Co., no. 4158, May 25, 1916. Due West, Oakland Co., no. 7909, June 1, 1927. Keweenaw Co.: on bluffs at Cliff Mine, no. 154, Aug. 1, 1884; on rocky shores of Lake Superior, no. 154a, Sept. 12, 1887.

Var. INTERMEDIA (DC.) O. A. F. in *Mich. Acad. Sci., Ann. Rep.,* 19: 256. 1917 (var. *kamchatica* Fischer in DC., *Syst.,*

2:231. 1821). — The varietal name *intermedia* has priority of position over *kamchatica,* since it precedes *kamchatica* on the same page in DC., *loc. cit.* Our plants, though far removed from the region of distribution as given by Hopkins, must nevertheless be placed here in accordance with the characters used by him. Rochester, Oakland Co., no. 1533½, July 4, 1896.

ARABIS GLABRA (Linn.) Bernh. — This species and *A. Drummondii* may be readily confused in the young, flowering stage. Wayne Co.: Detroit, no. 1455, June 15, 1894, and no. 8687, June 17, 1930; Palmer Park, no. 1455a, June 16, 1894; Nankin, no. 7405, June 10, 1925; Livonia, no. 8420, June 4, 1929, and no. 9450, July 18, 1933. Keweenaw Co.: Cliff Mine, no. 1455c, June 28, 1895; Agate Harbor, no. 11641, June 27, 1937. Woodville, Newaygo Co., no. 5960, Aug. 4, 1921. Grand Ledge, Eaton Co., no. 6570, June 10, 1923. Tecumseh, Lenawee Co., no. 7978, June 21, 1927. Bloomfield, Oakland Co., no. 8883, June 9, 1931.

Var. FURCATIPILIS Hopkins. — The pubescence of the stem base is of appressed branched hairs. Zoo Park, Oakland Co., no. 4208, June 17, 1916. South Rockwood, Monroe Co., no. 4943, June 16, 1918. Detroit, Wayne Co., no. 8688, June 17, 1930.

ARABIS OVATA (Ph.) Poir. — Ingham Co.: Williamston, no. 100b, May 28, 1905; East Lansing, no. 6526, June 9, 1923. Mackinac Island, Mackinac Co., no. 100a, June 20, 1895. Oakland Co.: Rochester, no. 2084½, June 16, 1909; Parkedale, no. 3426, June 8, 1913; Franklin, no. 5521, June 24, 1920. Copper Harbor, Keweenaw Co., no. 4001½, July 8, 1915. Detroit, Wayne Co., no. 8689, June 17, 1930.

Var. **glabrata** (T. and G.), comb. nov. (*Arabis hirsuta* var. *glabrata* T. and G., *Fl. N. Am.,* 1:80. 1838). — Cliff Mine, Keweenaw Co., no. 100, June 26, 1884, and no. 100c, July 3, 1895.

ARABIS PATULA (Graham) Torrey at least as to name bringing synonym (*A. brachycarpa* (T. and G.) O. A. F. in *Asa Gray Bulletin,* 2:46. Oct. 1, 1894). — This combination is usually accredited to Britton in *Mem. Tor. Bot. Club,* 5:174. 1894; but no combination in that volume *can claim effective publication before Jan. 18, 1895,* the time of its general distribution. It is true that each fascicle was sent to editors for review as soon as printed and has the date of printing on the first page, but that does not constitute valid publication under the International

Rules. At the general distribution Parke, Davis and Co. and I received our copies Feb. 15, 1895, more than a month after the publication of the first number of the third volume of the *Asa Gray Bulletin.* I should, therefore, date publications of the latter as of Jan. 1, 1895, and of the former as of Jan. 18, 1895, in as much as it is known that a copy had reached the Pacific Coast as early as Jan. 25, 1895.

I had a long correspondence with C. A. Weatherby, of the Gray Herbarium, in regard to the valid date of publication of the fifth volume of the *Memoirs of the Torrey Botanical Club*, and after looking up all the known data pertaining to the matter he finally agreed with me that under the International Rules the valid date of publication of that volume and of all combinations made in it could not antedate Jan. 18, 1895, in the light of present knowledge. The *Asa Gray Bulletin* was published quarterly, and in the first nine issues only the month was given as date of issue, but the actual date of issue was always the first of the month of the issue. At my personal request the actual date of issue was placed under the title on the first page and continued to appear there in subsequent numbers as long as Miss C. G. Du-Bois continued as editor.

The mature fruiting pedicels of this species are said to be from erect to divaricately spreading. My experience with it indicates that this is true of the immature pedicels only, and that the mature pedicels are deflexed. Keweenaw Co.: Cliff Mine, no. 55, Aug. 20, 1883, no. 156, Aug. 1, 1884, and no. 11361, July 16, 1936; Eagle River, no. 5971a, Aug. 16, 1921; West Bluff, no. 10938, July 25, 1935.

Var. **stenocarpa** (Hopkins), comb. nov. (*Arabis divaricarpa* var. *stenocarpa* Hopkins, *Rhodora,* 39:133. 1937). — Scarce. Mt. Brockway, Keweenaw Co., no. 11968, June 23, 1938.

ARABIS DRUMMONDII A. Gr.[5] — Pedicels and fruit erect; no stellate pubescence. Keweenaw Co.: Cliff Mine, no. 55a, Aug. 20, 1883; Copper Harbor, no. 5966½, Aug. 16, 1921; Eagle Harbor, no. 10937, July 25, 1935.

[5] In the herbarium of Parke, Davis and Co. there is a specimen from Cape May, N. J., collected by A. Commons of Faulkland, Del., July 20, 1881, and distributed as *Arabis* (without specific name); also specimens from Minneapolis, Minn., G. B. Aiton, May, 1891, and from Colorado (without place), Thomas Hogg, July, 1872.

Var. PRATINCOLA (Greene) Hopkins. — The radical leaves are pubescent, with branched hairs. Hunter's Point, Keweenaw Co., no. 11274, July 14, 1936.

ARABIS HOLBOELLII Hornem. — Infrequent. West Bluff, Keweenaw Co., no. 11942, May 30, 1939.

ARABIS RETROFRACTA Graham. — Rocky grounds. Keweenaw Co.: West Bluff, no. 11959, June 23, 1939; Hebard Park, no. 11977, June 23, 1939.

ARABIS VIRIDIS Harger var. HETEROPHYLLA (O. A. F.) O. A. F. (*A. laevigata* var. *heterophylla* O. A. F., *Mich. Acad. Sci.*, *Ann. Rep.*, 19 : 248. 1917; *A. viridis* var. *Deamii* Hopkins, *Rhodora*, 39 : 157. 1937). — Other collections are as follows: Oakland Co.: Parkedale, no. 2642, June 9, 1912, no. 2790, June 30, 1912, and no. 6951, July 2, 1924; Temperance, no. 7996, July 13, 1927. Wayne Co.: Nankin, no. 7405, June 10, 1925; Livonia, no. 8420, June 11, 1929.

SPIRAEA LATIFOLIA (Ait.) Bork. — Rare. On shores of Lac La Belle, Keweenaw Co., no. 12102, Aug. 16, 1939.

Var. SEPTENTRIONALIS Fern. — On shores and low wet ground. First time recorded for Michigan. Houghton Co.: Little Traverse Bay, no. 12029, July 28, 1939; Rice Lake region, no. 12050, July 28, 1939.

LATHYRUS PRATENSIS Linn. — Yellow pea. The flowers are bright golden yellow, with as many as thirteen in a raceme. In fields at Inkster, Wayne Co., no. 8905, June 16, 1932.

LATHYRUS TUBEROSUS Linn. — Bank of roadbed of the Michigan Central Railroad. Washtenaw Co.: Scio, no. 8705, June 24, 1930; Wiard, no. 8969, Aug. 4, 1932. Wayne Co.: Denton, no. 8958, July 21, 1932; Inkster, no. 8976, Aug. 11, 1932; Dearborn, no. 8990, Aug. 11, 1932.

SOJA MAX (Linn.) Piper. — Soy bean. Along a fence near an elevator in Dearborn, Wayne Co., no. 8986, flower Aug. 11 and fruit Sept. 29, 1932. The lower part of the plant is erect and bushy, but the upper parts are vinelike.

GERANIUM SANGUINEUM Linn. — Bloody cranesbill. Found in a grassy field and on roadside borders in the vicinity of Bloomfield Village, Oakland Co., no. 8884, June 9, 1932.

TRIBULUS TERRESTRIS Linn. — Caltrop. Railway roadsides. Dearborn, Wayne Co., no. 8987, Aug. 11, 1932.

EUPHORBIA PSEUDONUTANS Thell. (*E. hypericifolia* Mx., Ell., A. Gr., and most American authors, not Linn.; *E. nutans*, American authors, not Lag.; *E. Preslii*, American authors, not Guss.). — The plant commonly known in this country as *E. Preslii*, but not the species of Gussoni, which is the same as *E. nutans* Lag. of Mexico, according to Thellung. In shady places the leaves are broad and short, ovate; in sunny spots, long and narrow, oblong. On waysides mainly but also on borders of streams and in fields. Wayne Co.: Ecorse, no. 8832, Oct. 7 and 28, 1930; Taylor, no. 8837, Oct. 7, 1930; Wayne, no. 8931, July 14, 1931; River Rouge, nos. 9334 and 9335, Sept. 14, 1932. Wiard, Washtenaw Co. no. 8968, Aug. 4, 1931.

Var. HIRSUTA (Torr.) O. A. F. (*Euphorbia hirsuta* (Torr.) Wieg.; *E. Rafinesquii* Greene). — In similar situations but more frequent in fields and pastures than the species proper. Wayne Co.: Wayne, no. 8932, July 14, 1931; Inkster, no. 8984, Aug. 11, 1931.

EUPHORBIA GLYPTOSPERMA Engelm. — In sand and cinders. Inkster, Wayne Co., no. 8973, Aug. 11, 1931.

ILEX VERTICILLATA (L.) A. Gr. var. CYCLOPHYLLA Robinson. — Scarce; in swampy lands. Shores of Rice Lake, Houghton Co., no. 12171½, Sept. 19, 1939.

Var. TENUIFOLIA (Torr.) Wats. — The most frequent variety of this species to be found in the Copper Country. Generally called "Michigan holly." Northwest of Cliff Mine, Keweenaw Co., no. 622, July 26, 1888. Houghton Co.: Lake Roland, no. 10228, Aug. 15, 1934; shores of Torch Lake, no. 11148, Nov. 5, 1935; Electric Park, no. 11631, June 22, 1937; Rice Lake region, no. 12171, Sept. 19, 1939.

RHAMNUS CATHARTICA Linn. — Frangula, buckthorn. In swampy woods at Livonia, the first and only occurrence known in Wayne Co., though the plant was found several years ago in Oakland Co. Trees fifteen to twenty feet in height. Livonia, Wayne Co., no. 9448, July 11, 1933.

SIDA SPINOSA Linn. — A small waif along railroad. Taylor, Wayne Co., no. 8835, Oct. 7, 1930.

SIDA HERMAPHRODITA (Linn.) Rusby. — Virginia mallow. In low moist grounds, attaining a height of seven or eight feet. Sheldon, Wayne Co., no. 8941, July 14, 1931.

MALVA BOREALIS Wallm. (*M. pusilla* Sm.). — On roadsides and in waste places, where it has much the appearance of the common low mallow (*M. rotundifolia* Linn.), no. 9008, with which it is associated. It could be distinguished from the latter only by its prominently rugosely reticulated fruits. Dearborn, Wayne Co., no. 9002, Sept. 29, 1931.

VIOLA LABRADORICA Schrank. — In crevices of rocks on shores of lakes. Keweenaw Co.: Eagle Harbor, no. 9743, June 20, 1934; Hunter's Point, no. 11285, July 14, 1936; Hebard Park, no. 11974, June 23, 1939. Misery Bay, Ontonagon Co., no. 10707, May 19, 1935.

PETROSELINUM HORTENSE Hoffm. — Parsley. The common parsley is found as an escape to waste grounds. Beal does not list it. Houghton Co.: shores of Torch Lake, no. 11416, July 24, 1936; Lake Linden, no. 12228, Sept. 29, 1939.

PYROLA CHLORANTHA Swz. — Shinleaf. The typical shinleaf is very scarce. It is found in rich moist woods. Eagle Harbor, Keweenaw Co., no. 11868, Oct. 6, 1938.

Var. PAUCIFOLIA Fern. — This variety is not much more frequent than the typical one. Cliff Mine, Keweenaw Co., no. 304, Aug. 6, 1885. Lake Linden, Houghton Co., no. 10090, July 26, 1934.

EPIGAEA REPENS L. — Mayflower. Fernald (*Rhodora,* 41 : 446. 1939) has restricted the specific type to the southern plant with scabrous leaves. The northern plant with smoothish leaves he calls *E. repens* L. var. *glabrifolia* Fernald. This variety has white flowers and is commonly found under evergreens but sometimes occurs in the open, in fields or on hillsides under deciduous trees. Occasionally it flowers in the autumn. Throughout Michigan. Cliff Mine, Keweenaw Co., no. 10, June 12, 1883. Vicinity of Lake Linden, Houghton Co., no. 9612, May 11, 1934, no. 10677, Nov. 21, 1934, and no. 11934, May 18, 1939. Oxford, Oakland Co., on wooded hillsides, no. 4450½, May 20, 1917, and in open fields along roadsides, no. 5219, April 27, 1919.

Var. GLABRIFOLIA Fern. f. **rosea**, f. nov. — *Floribus roseis.* Flowers are pale rose or pink. I have never seen the pink and the white flowers on the same plant. A good color form. Lake Linden, Houghton Co., no. 11932, May 18, 1939.

VACCINIUM OVALIFOLIUM Sm. — Bilberry. The bilberry is frequent

in woods but is not nearly so abundant as the common huckleberry (*V. membranaceum* Dougl.). Lake Linden, Houghton Co., no. 9697, June 7, 1934. On the Gratiot Range, Keweenaw Co., no. 12075, Aug. 8, 1939.

CONVOLVULUS SEPIUM Linn. var. FRATERNIFLORUS Mack. & Bush. — On railroad banks. There are often three peduncles from the same axil, usually two, and sometimes only one. Taylor, Wayne Co., no. 8836, Oct. 7, 1930. Frequent.

LYCOPUS RUBELLUS Moench. var. ARKANSANUS (Fresenius) Benner (*L. arkansanus* Fresen.). — Plant puberulent. Wayne, Wayne Co., no. 7151, Sept. 10, 1924.

PHYSALIS IXOCARPA Brot. — Strawberry tomato. In borders of brush. Dearborn, Wayne Co., no. 8982, Aug. 11, 1931.

NICANDRA PHYSALODES (L.) Pers. — Apple of Peru. The apple of Peru is not listed by Beal. It is an escape to waste grounds. On shores of Torch Lake, Houghton Co., no. 12226, Sept. 28, 1939.

PENTSTEMON LAEVIGATUS Sol. — Beard tongue. Flowers gradually enlarged upward, small, white with violet veins; stems glabrous and more or less shining. Wayne Co.: Beach Road (Bach and Gladewitz, July 6, 1930), no. 8723, Aug. 5, 1930; Mack Woods, Detroit, no. 2036, Aug. 3, 1907. Scarce in southeastern Michigan.

Var. DIGITALIS (Sweet) A. Gr. (*Chelone Digitalis* Sweet). — Flowers much larger than those of species proper, abruptly dilated from near the base; stems glabrous and shining. Nine-Mile Road, Oakland Co., no. 1916a, Aug. 6, 1910. Algonac, St. Clair Co., no. 4229, June 22, 1916. Monroe, Monroe Co., no. 5822, June 9, 1921. Washington, Macomb Co., no. 5897, June 21, 1921. Wayne Co.: Detroit, no. 8685, June 17, 1930; noted at Livonia, July 8, 1930.

Var. **calycosus** (Small), comb. nov. (*Pentstemon calycosus* Small). — The internodes of the lower part of the stem are noticeably puberulent, and the calyx lobes are very narrow and long, often five lines long; leaves thinner, broader at base and clasping; otherwise like var. *Digitalis*. The color of the flower, white with violet veins, is much alike in all three varieties as found here. Pennell thinks my plant may be a hybrid between *P. Digitalis* and *P. calycosus* because the anthers are slightly pubescent. *Gray's New Manual* disposes of the matter by making the two synonymous. I think that on account of the puberulent

stem and elongated calyx lobes it may be well to maintain *calycosus* as a variety parallel with *Digitalis*. Belle Isle in Detroit River, no. 1916, June 20, 1905.

VERONICA ANAGALLIS-AQUATICA Linn. var. **terrea,** var. nov. — *Planta terrestris. A typica specie sepalis acutis vel obtusis, capsula orbiculata vel ovata, stylo longiore differt.* Plant slender, smaller in all its parts, less fleshy than species; terrestrial; in moist sand; one and one-half feet or less high, simple or branched throughout, glabrous except for a trace of short-stalked glands on some of the pedicels, which are two and one-half lines long in flowering and a line longer in fruiting stage; sepals acute or obtuse; capsule orbicular or ovoid (three lines long), emarginate; style three-quarters line to one and one-quarter lines long. Seems to be intermediate between *V. Anagallis-aquatica* and *V. catenata* var. *glandulosa*, containing characters of each but with a longer style than either. In Europe there is a *V. Anagallis* f. *terrestris* Ascherson growing in similar situations, but that is said to be simple. It may be the same as this. I have seen no specimens of it. Sandy banks of Middle River Rouge and on old wood roads at Northville, Wayne Co., no. 9105, June 22 and July 13, 1932.

PLANTAGO PSYLLIUM Linn. — Fleaweed. Two stations were found, with about six plants in all. Detroit, Wayne Co., no. 9350, Sept. 15, 1932.

HOUSTONIA PURPUREA Linn. var. CALYCOSA A. Gr. (*H. lanceolata* (Poir.) Britt.). — Bluets. Our first acquaintance with the variety. Gladewitz found it here in 1931 and referred it to var. *longifolia* (Gaertn.) A. Gr. It has narrow or ovate-lanceolate leaves. Not included by Beal in his *Michigan Flora* nor in his Supplement. In so far as I am aware this is the first report from Michigan. Plentiful in low grounds in Redford Township, Wayne Co., no. 9196, July 20, 1932.

SOLIDAGO BICOLOR L. var. PANICULATA O. A. F. — Described from Algonac specimens, but also found on the Keweenaw Peninsula, and in both instances within the influences of the shore waters and spray. Vicinity of Esrey Park, Keweenaw Co., no. 12222, Sept. 25, 1939.

SOLIDAGO BICOLOR L. var. SPATHULATA O. A. F. — Another Keweenaw station was found for this variety. Vicinity of Esrey Park, Keweenaw Co., no. 12221, Sept. 25, 1939.

SOLIDAGO RIGIDIUSCULA (T. and G.) Porter. — This goldenrod is not listed by Beal. Not frequent. Near Hebard Park, Keweenaw Co., no. 12158, Sept. 5, 1939.

SOLIDAGO RANDII (Porter) Britt. — On dry rocky grounds. Not listed by Beal. Keweenaw Co.: Eagle Harbor, nos. 11754 and 11756, June 27, 1938, and no. 12211, Sept. 25, 1939; near Esrey Park, no. 12217, Sept. 25, 1939.

Var. MONTICOLA (Porter) Fern. — Same situations as, and passing into, the typical variety. Not listed by Beal. Near Eagle Harbor, Keweenaw Co., no. 12212, Sept. 25, 1939.

ANAPHALIS OCCIDENTALIS (Greene) Heller. — Not listed by Beal. Near Eagle Harbor, Keweenaw Co., no. 11867, Oct. 6, 1938, and no. 12213, Sept. 25, 1939.

RUDBECKIA TRILOBA L. — Brown-eyed Susan. Found on ballast ground, so may be an escape from cultivation. On shores of Torch Lake, Houghton Co., no. 12229, Sept. 28, 1939.

ANTHEMIS TINCTORIA Linn. — An escape from cultivation. Plentiful near the Osceola swamp on waste ground near Calumet, Houghton Co., no. 11675, July 27, 1937.

ARTEMISIA CAUDATA Mx. — Wild wormwood. This species has been found on the Keweenaw Peninsula, thus extending its Michigan range far to the north and throughout the state. The manuals call it an annual or biennial, but in Michigan the species is certainly a perennial. Usually found in the yellow sand of the lake shores. Bete Grise Bay, Keweenaw Co., no. 10946, July 25, 1935. Little Traverse Bay, Houghton Co., no. 12026, July 28, 1939.

SONCHUS ULIGINOSUS Bieb. — This species of sow thistle seems to have spread throughout the state. Houghton Co.: Calumet, no. 11683, Aug. 10, 1937; Lake Linden, no. 11987, July 17, 1939.

ARNICA WHITNEYI Fernald. — A new station for this plant was found between Eagle Harbor and Copper Harbor at Hebard Park. On a visit in late June to Copper Harbor cemetery, where I collected it in 1884, I found it still there and in considerable quantity. The local inhabitants call it "wild sunflower." Keweenaw Co.: Hebard Park, no. 11645, June 27, 1937; Copper Harbor cemetery, no. 11647, June 27, 1937.

LAKE LINDEN, HOUGHTON COUNTY
MICHIGAN

ADDITIONS TO THE FLORA OF MICHIGAN. III

CLARENCE R. HANES

THE species listed in this paper represent collections made in Kalamazoo County during the year 1939 by Mrs. Florence N. Hanes and the writer. Specimens have been deposited in the herbaria of the University of Michigan, the Academy of Natural Sciences of Philadelphia, the Bailey Hortorium, the University of Oklahoma, and the National Herbarium. The identification of the plants has been confirmed at these institutions.

All species marked with an asterisk are new to Michigan records, so far as can be determined.

List of Species

*Eragrostis diffusa Buckl. — In a street in Schoolcraft, July 22, 1939, no. 709. The range of this grass is southern United States.

*Carex Frankii Kunth. — In a low open wood in the east-central part of Section 33, Climax Township, July 7, 1939, no. 429. It is unusual to find this sedge in Kalamazoo County, since its range is south of Michigan. According to Dr. F. J. Hermann, it has not been reported for the two northern tiers of counties of Indiana. Plants quite closely associated with it were *Carex crinita*, *Carex intumescens*, *Scirpus lineatus*, and *Penstemon Digitalis*.

Ranunculus hispidus Michx. var. falsus Fernald. — In an oak woodland in the north-central part of Section 5, Climax Township, May 15, 1939, no. 19. The variety prefers drier soil than the species. Apparently there have been no recent collections of this plant in Michigan. Miss Betty Robertson, of the University of Michigan, found herbarium specimens collected by Dr. R. M. Gibbs near Kalamazoo in May, 1874; by L. J. Cole near East Lansing in May, 1895; and by H. C. Sheels near Grand Rapids in May, 1895.

Arabis viridis Harger. — On sandy border of thin woods, one-half mile southeast of Hampton Lake, June 26, 1939, no. 1919. The

range map of Dr. Milton Hopkins[1] gives two main sections of the United States where this species of Arabis is found: (1) New York and New England and (2) Missouri and the area southwest. The lone previous Michigan record is from near Muskegon. In Kalamazoo County it has been collected at one station in Texas Township and at three in Portage Township.

Rubus Wheeleri Bailey. — In a swampy meadow, bordered by tamarack, one-fourth mile northwest of Hampton Lake, July 20, 1939, no. 629. This Michigan endemic was first collected in 1891 by Dr. L. H. Bailey in a tamarack swamp near Lansing. Soon afterward the station was cleared and drained. In the early 1930's it was again found near Lansing, by Dr. Bailey and others, but this second location also has been destroyed. The Hampton Lake specimen is the only plant of this species Dr. Bailey has seen other than those found near Lansing.

*Trichostema dichotomum L. — In sandy sterile soil on border of woods, near the northern edge of Section 7, Oshtemo Township, Sept. 19, 1939, no. 1739. This would appear to be a plant restricted mostly to the Atlantic Coastal Plain and, therefore, may be adventive in Michigan. Still, Kalamazoo County has some twenty of the so-called Atlantic Coastal Plain species that are found around the southern end of Lake Michigan and in the extreme southwestern portion of our state. The station where *T. dichotomum* was collected is near a section of Kalamazoo County where several other Atlantic Coastal Plain species occur.

Gratiola neglecta Torr. (*G. virginiana* of *Gray's Manual*, Seventh Edition). — On the muddy border of an old creek bed, in the central part of Section 31, Wakeshma Township, Aug. 1, 1939, no. 949. Collected with *Lindernia dubia* var. *major*. Apparently no reports of this species from Michigan have been made since Winchell's *Catalogue*[2] appeared. Dr. Francis W. Pennell, of the Academy of Natural Sciences of Philadelphia, who checked this plant, had previously seen no specimen from Michigan.

Schoolcraft, Michigan

[1] "Arabis in Eastern and Central North America," *Rhodora*, 39: 157. 1937.

[2] Winchell, N. H., "Catalogue of Phaenogamous and Acrogenous Plants Found Growing Wild in the Lower Peninsula of Michigan and the Islands at the Head of Lake Huron," *First Biennial Report of the Geological Survey of Michigan* [for 1860], pp. 245–330. 1861.

A CONCLUDING LIST OF DESMIDS FROM ISLE ROYALE, MICHIGAN

GERALD W. PRESCOTT

ISLE ROYALE in northern Michigan lies within what might be termed the North Temperate desmid belt. In this latitude of North America strong glaciation has resulted in many lakes and bogs which are favorable to the production of a rich desmid flora. With a few exceptions, however, the algae collections[1] which I have examined from this island have proved to be nontypical of desmid habitats in the surrounding area in respect to number of individuals. The brevity of the present list of species and of those lists previously published (7, 8, 9) is explained by the fact that not many of the Isle Royale collections in which desmids appear were taken with special attempts to obtain these plants. It is well known that particular techniques are required in gathering representative samples of desmids. As I pointed out (9), plankton species are conspicuously absent because tow collections were not made in the Isle Royale survey. There is every reason to believe that a rich and interesting flora awaits the special collector of desmids on this island, and no doubt future studies will add many species to those already reported.

My unpublished observations of Wisconsin desmids indicate a greater similarity between the flora of that state and of Isle Royale than was previously thought to exist (7). The desmids of the island, as might be expected, are much the same as those of Canada, Newfoundland, and, in general, of New England. When the desmid records for Michigan are compared with those for Massachusetts, however, only thirty-one per cent of the species are found to be common to both states (3). This is in keeping with the fact, which seems to be well established at present, that many species of desmids in the flora of the Atlantic coastal plain are limited to that region

[1] These samples were collected in the biological survey of Isle Royale conducted by the University of Michigan and authorized by the Fifty-fifth Legislature of the State of Michigan.

in North America. This is also true for the central part of the continent but for a much smaller number of species.

The 221 species and varieties from Isle Royale are distributed among the following genera:

Cylindrocystis	2	Arthrodesmus	3
Spirotaenia	1	Xanthidium	7
Netrium	2	Staurastrum	61
Penium	2	Euastrum	23
Closterium	22	Micrasterias	19
Spinoclosterium	1	Desmidium	5
Pleurotaenium	4	Hyalotheca	2
Tetmemorus	2	Gymnozyga	1
Cosmarium	64		

I wish to express my appreciation to the American Association for the Advancement of Science for a grant in aid which facilitated the preparation of an iconograph used in this study.

List of Species

Cylindrocystis Brebissonii Menegh.; Krieger, *Die Desmidiaceen*, Teil 1, Lief. 1 : 207, Pl. 6, Figs. 4–7. 1933.

Length 35.1 μ, width 15.6 μ. Pl. II, Fig. 14. Moose Lake.

Spirotaenia condensata De Bréb.; Krieger, *Die Desmidiaceen*, Teil 1, Lief. 1 : 181, Pl. 2, Fig. 1. 1933.

Our specimens are proportionately very long and frequently somewhat sigmoid. Length 200–272 μ, width 23.4 μ. Pl. I, Fig. 1. Moose Lake.

Netrium digitus var. lamellosum (De Bréb.) Grönblad; Krieger, *Die Desmidiaceen*, Teil 1, Lief. 1 : 219, Pl. 7, Fig. 6. 1933.

Length 155–191.5 μ, width at constriction 40 μ, maximum width 42.5 μ, width at poles 15.6 μ. Pl. II, Fig. 15. Moose Lake.

Netrium digitus var. Naegelii (De Bréb.) Krieger, *Die Desmidiaceen*, Teil 1, Lief. 1 : 218, Pl. 8, Figs. 4–5. 1933.

Length 156 μ, width 39.5 μ. Pl. II, Fig. 16. Moose Lake.

Penium phymatosporum Nordstedt; West and West, *British Desmidiaceae*, I : 91, Pl. 6, Figs. 9–11. 1904.

Length 35 μ, width 17 μ. Moose Lake, Hidden Lake.

Closterium angustatum Kuetz.; Krieger, *Die Desmidiaceen*, Teil 1, Lief. 2 : 363, Pl. 35, Figs. 2–4. 1935.

Wall yellowish, with four to six coarse striations. Length 400 μ, maximum width 19.5 μ, width at poles 11.7 μ. Pl. I, Figs. 13–15. Moose Lake, Hidden Lake.

CLOSTERIUM ARCHERIANUM Cleve; Krieger, *Die Desmidiaceen,* Teil 1, Lief. 2 : 368, Pl. 36, Figs. 7–8. 1935.

Wall yellowish brown, particularly in older half of cell, with about fifteen striations visible. Length 148 μ, maximum width 20.5 μ, width at poles, 3.7 μ. Pl. I, Fig. 2. Passage Island.

CLOSTERIUM BAILLYANUM De Bréb.; Krieger, *Die Desmidiaceen,* Teil 1, Lief. 2 : 327, Pl. 26, Figs. 7–8. 1935.

Wall colorless but becoming slightly tinged with yellow in age. Length 429 μ, maximum width 39 μ, width at poles 19.5 μ. Pl. I, Figs. 3–5. Wallace Lake. New record for Michigan.

CLOSTERIUM DIANAE Ehr.; Krieger, *Die Desmidiaceen,* Teil 1, Lief. 2 : 294, Pl. 19, Figs. 9–11; Pl. 20, Fig. 1. 1935.

Wall colorless, smooth. Length (distance between apices) 187 μ, width 18.5 μ. Pl. I, Fig. 9. Moose Lake.

CLOSTERIUM INTERMEDIUM var. HIBERNICUM W. & G. S. West; West and West, *British Desmidiaceae,* I : 126, Pl. 14, Fig. 6. 1904.

Wall yellow to golden brown, with about eight striations visible. Length 312 μ, width 15.6 μ, width at poles 7.8 μ. Pl. I, Fig. 20. Moose Lake.

CLOSTERIUM LEIBLEINII Kuetz.; Krieger, *Die Desmidiaceen,* Teil 1, Lief. 2 : 283, Pl. 17, Figs. 5–7. 1935.

Wall smooth, colorless. Length (distance between apices) 195 μ, width 39 μ. Pl. I, Fig. 21. Siskiwit Lake.

CLOSTERIUM LUNULA var. INTERMEDIUM Gutw.; Krieger, *Die Desmidiaceen,* Teil 1, Lief. 2 : 303, Pl. 21, Fig. 3. 1935.

Wall smooth, colorless, suddenly tapering to broadly truncate poles. Length 522 μ, width 78–82 μ. Pl. I, Fig. 19. Locality of collection not given.

CLOSTERIUM NAVICULA (De Bréb.) Lütkem.; Krieger, *Die Desmidiaceen,* Teil 1, Lief. 2 : 257, Pl. 12, Figs. 8–10. 1935.

Length 50 μ, width 15 μ. Moose Lake.

CLOSTERIUM PARVULUM Naeg.; Krieger, *Die Desmidiaceen,* Teil 1, Lief. 2 : 275, Pl. 16, Figs. 14–17. 1935.

Wall smooth, colorless. Chloroplasts with one, rarely two, pyrenoids. Length (distance between apices) 85.8 μ, width 8 μ. Pl. I, Fig. 22. Moose Lake.

CLOSTERIUM PARVULUM var. MAJUS West; Krieger, *Die Desmidiaceen,* Teil 1, Lief. 2 : 277, Pl. 16, Fig. 18. 1935.

Wall smooth, colorless, cells somewhat stouter and larger throughout than in typical plant. Length (distance between apices) 124.8 μ, width 19.5 μ, width at poles 3 μ. Hidden Lake.

CLOSTERIUM PSEUDODIANAE Roy; West and West, *British Desmidiaceae,* I : 132, Pl. 15, Figs. 7–8. 1904.

Wall smooth, colorless. Length 185–196 μ, width 11–13 μ. Wallace Lake.

CLOSTERIUM RALFSII var. HYBRIDUM Rab.; West and West, *British Desmidiaceae,* I : 183, Pl. 24, Figs. 8–13. 1904.

Wall light tawny yellow, with twenty-five to thirty fine striae visible. Length 400 μ, width 31.2 μ. Pl. I, Figs. 6–8. Moose Lake.

CLOSTERIUM STRIGOSUM var. ELEGANS (G. S. West) Krieger, *Die Desmidiaceen,* Teil 1, Lief. 2 : 300, Pl. 20, Fig. 12. 1935.

Wall smooth, colorless. Length 429 μ, width 31.2 μ. Pl. I, Figs. 11–12. Moose Lake.

CLOSTERIUM STRIOLATUM Ehr.; Krieger, *Die Desmidiaceen,* Teil 1, Lief. 2 : 337, Pl. 28, Figs. 8–9; Pl. 29, Fig. 9. 1935.

Wall yellow-brown, with thirty to forty striae visible. Length 333 μ, width 37 μ, width at poles 10 μ. Pl. I, Figs. 16–18. Moose Lake.

CLOSTERIUM VENUS Kuetz.; Krieger, *Die Desmidiaceen,* Teil 1, Lief. 2 : 272, Pl. 16, Figs. 1–5. 1935.

Cells small, strongly curved, two pyrenoids in each chloroplast. Wall smooth, colorless. Length (distance between apices) 46.8 μ, width 7.8 μ. Pl. I, Fig. 10. Rock pool on Bat Island.

PLEUROTAENIUM EHRENBERGII (De Bréb.) De Bary; West and West, *British Desmidiaceae,* I : 205, Pl. 29, Figs. 9–11; Pl. 30, Fig. 1. 1904.

Length 390–429 μ, width 25–27.5 μ. Hidden Lake, Siskiwit Lake.

PLEUROTAENIUM TRUNCATUM var. FARQUHARSONII (Roy & Biss.) West and West, *British Desmidiaceae,* I : 205, Pl. 29, Figs. 5–6. 1904.

Length 429 μ, width 62.4 μ. Hidden Lake. New record for North America.

TETMEMORUS GRANULATUS (De Bréb.) Ralfs; West and West, *British Desmidiaceae,* I: 219, Pl. 32, Figs. 7–9. 1904.

Wall sparsely and regularly punctate. Length 140.4 μ, width 43.9 μ. Pl. II, Fig. 3. Moose Lake.

TETMEMORUS LAEVIS (Kuetz.) Ralfs; West and West, *British Desmidiaceae,* I: 222, Pl. 32, Figs. 11–16. 1904.

Wall smooth. Length 78 μ, width 23.4 μ. Pl. II, Figs. 1–2 Moose Lake and many other habitats on the island.

ARTHRODESMUS TRIANGULARIS var. INFLATUS W. & G. S. West West and West, *British Desmidiaceae,* IV: 99, Pl. 114, Figs. 14–15. 1912.

Length 23.4 μ, width 19.5 μ including spines, isthmus 6 μ. Pl. II, Fig. 13. Moose Lake.

DESMIDIUM APTOGONUM De Bréb.; West and West, and Carter, *British Desmidiaceae,* V: 242, Pl. 164, Figs. 1–3. 1923.

Cells triangular in end view, showing prominent apical extensions, by which the cells are adjoined, in front view. Length 19.5 μ, width 31.2 μ. Pl. II, Fig. 10. Moose Lake.

DESMIDIUM ASYMMETRICUM Grönblad, *Acta Soc. pro Fauna et Flora Fenn.,* 47 (4): 85, Pl. 1, Figs. 5–7. 1920.

Cells triangular in vertical view; in front view cells within filament turned at various angles so that lobes of semicells lie in different planes. Length 15.6–23.4 μ, width 27.3–28 μ. Pl. II, Fig. 11. Moose Lake.

DESMIDIUM BAILEYI var. MINOR Allorge and Allorge, *Rev. Algol.,* 5: 369, Pl. 15, Fig. 1. 1930.

Length 19.5 μ, width 19.5 μ. Pl. II, Fig. 12. Wallace Lake. New record for North America.

DESMIDIUM GREVILLEI (Kuetz.) De Bary; Smith, *Phytoplankton Inland Lakes Wis.,* Part II: 145, Pl. 88, Fig. 8. 1924.

In vertical view elliptic and with prominent nodules at the poles. Length 27–35 μ, width 45–47 μ. Pl. II, Fig. 9. Moose Lake.

DESMIDIUM SWARTZII C. A. Agardh; West and West, and Carter, *British Desmidiaceae,* V: 246, Pl. 163, Figs. 5–8. 1923.

Cells triangular in end view; apices of cells adjoined by very short, inconspicuous extensions. Length 15–17.5 μ, width 32–35 μ. Pl. II, Fig. 8. Hidden Lake.

HYALOTHECA DISSILIENS (Sm.) De Bréb.; West and West, and

Carter, *British Desmidiaceae,* V: 229, Pl. 161, Figs. 16–27. 1923.

Length 19.5 μ, width 31.2 μ. Pl. II, Figs. 5–7. Small pool near trail from Monument Rock to Tobin Harbor, widely distributed over the island.

HYALOTHECA MUCOSA (Mert.) Ehr.; West and West, and Carter, *British Desmidiaceae,* V: 235, Pl. 162, Figs. 1–4. 1923.

Length 17 μ, width 15.6 μ. Pl. II, Fig. 4. Moose Lake.

ALBION COLLEGE
ALBION, MICHIGAN

LITERATURE

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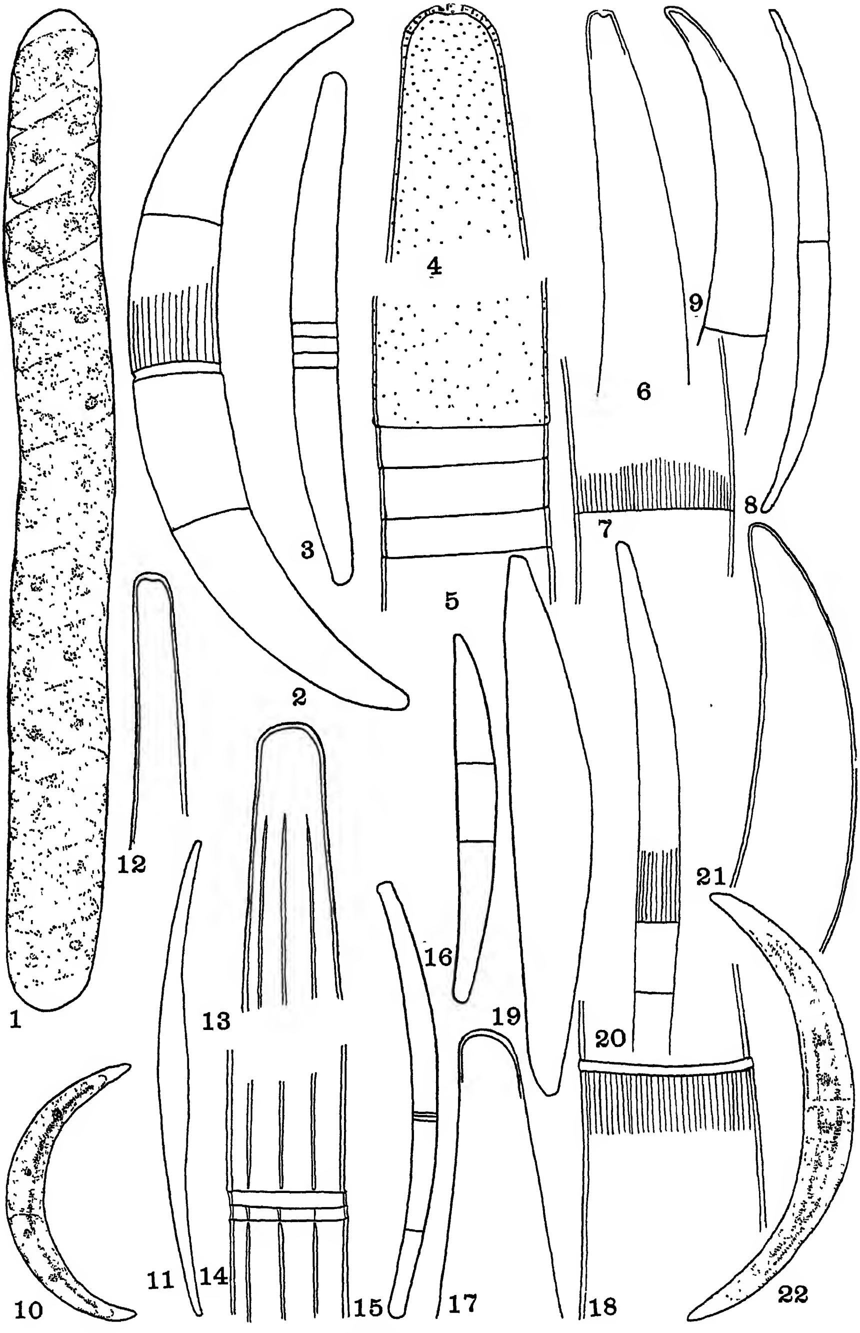
EXPLANATION OF PLATE I

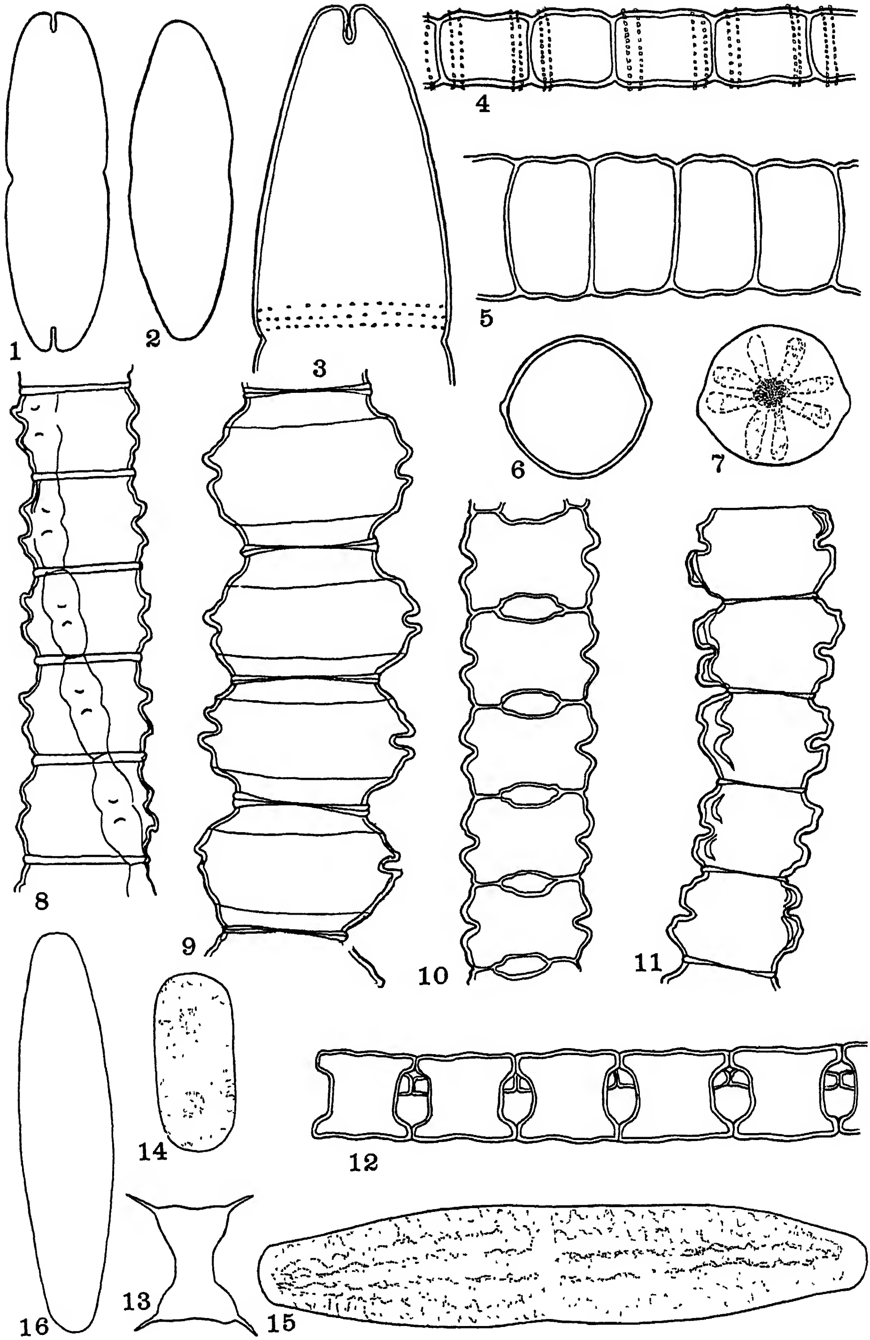
1. Spirotaenia condensata De Bréb. × 440
2. Closterium Archerianum Cleve. × 440
3–5. C. Baillyanum De Bréb. × 100
6–8. C. Ralfsii var. hybridum Rab. × 440
9. C. Dianae Ehr. × 440
10. C. Venus Kuetz. × 440
11–12. C. strigosum var. elegans (G. S. West) Krieger. Fig. 11, × 50; Fig. 12, × 440
13–15. C. angustatum Kuetz. Figs. 13–14, × 440; Fig. 15, × 100
16–18. C. striolatum Ehr. Fig. 16, × 220; Figs. 17–18, × 440
19. C. Lunula var. intermedium Gutw. × 100
20. C. intermedium var. hibernicum W. & G. S. West. × 50
21. C. Leibleinii Kuetz. × 440
22. C. parvulum Naeg. × 440



Desmids from Isle Royale

EXPLANATION OF PLATE II

1–2. Tetmemorus laevis (Kuetz.) Ralfs. × 440
3. T. granulatus (De Bréb.) Ralfs. × 330
4. Hyalotheca mucosa (Mert.) Ehr. × 440
5–7. H. dissiliens (Sm.) De Bréb. × 440
8. Desmidium Swartzii C. A. Agardh. × 440
9. D. Grevillei (Kuetz.) De Bary. × 440
10. D. Aptogonum De Bréb. × 100
11. D. asymmetricum Grönblad. × 440
12. D. Baileyi var. minor Allorge and Allorge. × 400
13. Arthrodesmus triangularis var. inflatus W. & G. S. West. × 440
14. Cylindrocystis Brebissonii Menegh. × 440
15. Netrium digitus var. lamellosum (De Bréb.) Grönblad. × 330
16. N. digitus var. Naegelii (De Bréb.) Krieger. × 220



Desmids from Isle Royale

DISTRIBUTION OF THE RANUNCULACEAE IN MICHIGAN *

BETTY M. ROBERTSON

BEAL'S *Michigan Flora*,[1] published in 1904, is the most recent systematic and distributional account of Michigan vascular plants as a whole available for reference. It was compiled at a time when the data pertinent to such an annotated list were very meager compared to the information now at one's disposal but still unassembled. Consequently, the student of the local flora has been seriously handicapped by the lack of a definitive, authoritative handbook. Until this difficulty has been solved by the publication of a comprehensive and detailed modern Flora of Michigan, it may be remedied in part by the presentation of careful studies of special groups, such as have already appeared in the *Reports* and *Papers* of the Michigan Academy of Science, Arts, and Letters for the Orchidaceae,[2] Violaceae,[3] Umbellales,[4] Ericales,[5] Cruciferae,[6] and Potamogeton.[7] It is with this end in view that a study of the Ranunculaceae is offered as a contribution to our knowledge of the state flora. In it are included all recently described species and varieties which have been found in Michigan. The nomenclature has been brought up to date throughout the family.

* Papers from the Department of Botany of the University of Michigan, No. 719.

[1] *Ann. Rep. Mich. Acad. Sci.*, 5: 1–147. 1904.

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[3] Thompson, Bertha E., "Distribution of the Violaceae of Michigan," *Pap. Mich. Acad. Sci., Arts, and Letters*, 1 (1921): 167–184. 1923.

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[5] *Idem*, "Distribution of the Ericales in Michigan," *ibid.*, 3 (1923): 166–191. 1924.

[6] Walpole, Branson A., "Distribution of the Cruciferae in Michigan," *Pap. Mich. Acad. Sci., Arts, and Letters*, 6 (1926): 307–349. 1927.

[7] Costing, Henry J., "Distribution of the Genus Potamogeton in Michigan," *Pap. Mich. Acad. Sci., Arts, and Letters*, 15 (1931): 141–171. 1932.

This paper is based primarily upon material in the herbaria of the University of Michigan and of Michigan State College. Only those introduced species have been admitted as established members of the state flora which have persisted without cultivation over a period of several years and whose occurrence in Michigan is confirmed by a record specimen. Species reported to have been found in the state but for which no corroborating specimen could be located are listed at the end. Because of limitation of space only a single citation for each county is ordinarily given, generally not of the first collection, but of the specimen with the most explicit data.

The majority of the Ranunculaceae which are represented in Michigan are distributed throughout the greater part of the state, only four being restricted, so far as is known, to the Upper Peninsula, and seven to the Lower Peninsula. From fifteen of the counties no specimens could be found of any of the forty species — a significant indication of how much botanical exploration remains to be done in Michigan.

I wish to thank Dr. F. J. Hermann for suggesting this study of the Ranunculaceae and for his kind assistance.

KEY TO THE GENERA OF RANUNCULACEAE IN MICHIGAN

a. Fruit an achene; carpels 1-ovuled
- *b.* Sepals imbricated in bud; lower leaves alternate or radical; plants not climbing
  - *c.* Petals evident, yellow or rarely white .... 1. Ranunculus
  - *c.* Petals none; sepals often large and petal-like
    - *d.* Flowers small, numerous, panicled, not subtended by an involucre .... 2. Thalictrum
    - *d.* Flowers few, large, showy, subtended by an involucre
      - *e.* Involucre remote from flower, leaflike
        - *f.* Plants glabrous, from a cluster of thick tuberous roots; achenes ribbed .... 3. Anemonella
        - *f.* Plants hairy or pubescent; roots not tuberous; achenes not ribbed .... 4. Anemone
      - *e.* Involucre close under flower, calyx-like .... 5. Hepatica
- *b.* Sepals valvate in bud; leaves opposite; plants climbing ... 6. Clematis

a. Fruit a follicle or a berry; carpels several-ovuled
- *b.* Fruit a follicle
  - *c.* Flowers regular
    - *d.* Petals none; sepals large, petal-like
      - *e.* Sepals white; leaves compound .... 7. Isopyrum
      - *e.* Sepals yellow; leaves simple, kidney-shaped .... 8. Caltha
    - *d.* Petals present
      - *e.* Petals large, spur-shaped .... 9. Aquilegia
      - *e.* Petals smaller, equal to or shorter than sepals, not spur-shaped

f. Pods sessile; leaves 5–7-parted. (See excluded species, p. 59.) .... Trollius
f. Pods long-stalked; leaves trifoliolate, evergreen .. 10. Coptis
c. Flowers irregular; upper sepal long-spurred .... 11. Delphinium
b. Fruit a berry
c. Flowers racemose; berries on conspicuous pedicels .... 12. Actaea
c. Flowers solitary; berries sessile, aggregated into a head 13. Hydrastis

1. RANUNCULUS [Tourn.] L.

a. Aquatic or semiaquatic plants
b. Leaves all submerged, repeatedly dissected
c. Leaves sessile, from mostly broad stipular sheaths, not often collapsing when withdrawn from water
d. Achenes 8–30, averaging 16; beak of achene about 1 mm. long 1. *R. longirostris*
d. Achenes very many, 30–60, averaging usually 40; beak of achene 0.2–0.5 mm. long .... 2. *R. subrigidus*
c. Leaves petioled, collapsing when withdrawn from water; stipular sheaths narrow except on immature leaves
d. Receptacle hairy; achenes 1.25–1.5 mm. long, frequently hairy at maturity .... 3. *R. trichophyllus*
d. Receptacle nearly naked; achenes 1.5–1.75 mm. long, glabrous at maturity .... 3a. *R. trichophyllus* var. *calvescens*
b. Leaves not all submerged, dissected, lobed, entire or denticulate
c. Leaves filiformly dissected
d. Not rooting out of water .... 4. *R. flabellaris*
d. Rooting out of water................ 4a. *R. flabellaris* f. *riparius*
c. Leaves not filiformly dissected
d. Leaves palmately divided
e. Plant floating or creeping; branches prostrate or only slightly ascending; 1–4-flowered; bracteal leaves absent, or few and very small .... 5. *R. Gmelini* var. *Purshii*
e. Plant upright; branches strongly ascending, 7–50-flowered; bracteal leaves numerous, the lower 1–4 cm. long 5a. *R. Gmelini* var. *prolificus*
d. Leaves simple, lanceolate or linear
e. Leaves 4–10 cm. long; achenes strongly beaked .. 6. *R. ambigens*
e. Leaves 0.5–5 cm. long; achenes mucronate with a short abrupt point
f. Leaves linear, filiform .... 7. *R. reptans*
f. Leaves spatulate or oblong .... 7a. *R. reptans* var. *ovalis*
a. Terrestrial plants but often in wet places
b. Achenes marginless; basal leaves entire or 3-lobed, all crenate
c. Petals large .... 8. *R. rhomboideus*
c. Petals small
d. Head of fruit cylindric or oblong; achenes very numerous; basal leaves all lobed or parted .... 9. *R. sceleratus*
d. Head of fruit subglobose; achenes few; basal leaves mostly not lobed
e. Basal cordate leaves with an open sinus

f. Peduncles, upper internodes, and leaf surfaces glabrous or essentially so .... 10. *R. abortivus*
f. Young peduncles (at least toward base), upper internodes, and often surfaces of youngest cauline leaves minutely pilose .... 10a. *R. abortivus* var. *acrolasius*
e. Basal leaves with a narrow or nearly closed sinus 10b. *R. abortivus* var. *eucyclus*
b. Achenes compressed, with an evident firm margin; leaves variously cleft or divided
c. Beak of achene long and strongly recurved; petals shorter than reflexed calyx .... 11. *R. recurvatus*
c. Beak of achene not both long and recurved; petals usually longer than calyx
d. Beak of achene long, more than half length of achene
e. Roots thickened; stems 1–4 dm. high; achenes 2–2.6 mm. wide
f. Leaf segments narrow, leaf appearing pinnate 12. *R. fascicularis*
f. Leaf segments broad, oblong or obovate; leaves palmately 3-cleft or divided
g. Pubescence spreading .... 13. *R. hispidus*
g. Pubescence appressed .... 13a. *R. hispidus* var. *falsus*
e. Roots slender; stems 3–8 dm. high; achenes 3–3.4 mm. wide 14. *R. septentrionalis*
d. Beak of achene short, not more than half length of achene
e. Plants usually creeping or ascending; sepals not reflexed
f. Flowers 2–2.6 cm. in diameter
g. Pubescence appressed .... 15. *R. repens*
g. Pubescence spreading
h. Plants creeping .. .. 15a. *R. repens* var. *villosus*
h. Plants erect .... 15b. *R. repens* var. *erectus*
f. Flowers not over 1.5 cm. in diameter. (See excluded species, p. 58.) .... *R. Macounii*
e. Plants erect; sepals reflexed
f. Leaflets stalked; head of fruit oblong or cylindric 16. *R. pennsylvanicus*
f. Leaflets sessile; head of fruit globose .... 17. *R. acris*

1. *Ranunculus longirostris* Godr. (*Rhodora*, 38: 18. 1936)

R. circinatus of American authors, not Sibth.
Batrachium divaricatum (Schrank) Wimm.
B. circinatum (Sibth.) Reichenb.

Ponds and slow streams.

Specimens examined. — Van Buren Co., H. S. Pepoon, June, 1906. Calhoun Co., Rice Creek, C. M. Tarzwell 258. Jackson Co., Portage Lake, E. B. Mains, June, 1913. Washtenaw Co., near Ann Arbor, E. W. Erlanson 116. Barry Co., Lake Independence, D. E. Miller 39. Ingham Co., Lake Lansing, C. F. Wheeler, June, 1900. Oakland Co., C. Billington, June, 1922. Macomb Co.,

Washington, D. Cooley, June, 1840. Kent Co., Grand Rapids, H. M. Bailey, June, 1892. Genesee Co., Flint, D. Clark 4016. Lapeer Co., C. K. Dodge, June, 1893. St. Clair Co., near Algonac, C. K. Dodge, Aug., 1903. Muskegon Co., Black Lake, C. D. McLouth, July, 1894. Gratiot Co., Alma, C. A. Davis, June, 1889. Osceola Co., Muskegon River, H. T. Darlington, Aug., 1916. Roscommon Co., near Houghton Lake, Darlington and Bessey, July, 1916. Antrim Co., C. Leavitt, in 1890. Emmet Co., Crooked River at Alanson, J. H. Ehlers 5346. Cheboygan Co., Carp Creek, C. O. Erlanson 259. Luce and Mackinac Co., Manistique Lake, D. E. Miller 154. Alger Co., Chatham, C. F. Wheeler, Sept., 1900. Gogebic Co., near Watersmeet, H. T. Darlington, Aug., 1919.

Reported from Ionia Co., shallow streams, Hubbardston (W. B. Drew, *Rhodora*, 38 : 43. 1936).

2. *Ranunculus subrigidus* W. B. Drew, *Rhodora*, 38 : 39. 1936

"Persistent style-base forming a short beak (0.2–0.5 mm.) at maturity; achenes very many (30–80) but usually about 40, averaging 1.25 mm. in length: stipular sheaths pubescent or not, usually $\frac{3}{4}$ to completely adnate to the petioles . . . . Closely resembles *R. longirostris* in habit; but normally each species has distinctive fruit characters. *R. longirostris* bears from 8 to 30 (average 16) carpels" (W. B. Drew, *Rhodora*, 38 : 12, 41–42).

Specimen examined. — Iron Co., Liver-light Lakes, F. P. Metcalf 2223 (U. S. National Herbarium).

3. *Ranunculus trichophyllus* Chaix. (*Rhodora*, 38 : 18. 1936)

R. aquatilis L. var. *capillaceus* DC.
Batrachium trichophyllum (Chaix) Bosch in Beal, *Michigan Flora.*

Slow-flowing waters and ponds.

Specimens examined. — Washtenaw Co., C. A. Davis, June, 1890. Barry Co., Hastings Fish Hatchery, C. M. Tarzwell 282. Oakland Co., Pontiac, June, 1838. St. Clair Co., Algonac, H. H. Rush, Aug., 1884. Gratiot Co., Alma, C. A. Davis, May, 1896. Cheboygan Co., Maple River, J. H. Ehlers 1141. Chippewa Co., Prentis Bay Creek, J. H. Ehlers 1356. Alger Co., K. K. Mackenzie, Aug., 1916. Marquette Co., C. A. Davis, July, 1906. Gogebic Co., near Watersmeet, Bessey and Darlington,

Aug., 1919. Ontonagon Co., Porcupine Mts., H. T. Darlington, Aug., 1919. Keweenaw Co., O. A. Farwell, Aug., 1888; Isle Royale, A. E. Foote, in 1868.

Reported from: Allegan Co., Salem Township, F. A. Loew, in 1913. Manistee Co., Manistee, F. P. Daniels, in 1903. Cheboygan Co., Black Lake, Beal and Wheeler, in 1892.

3a. *Ranunculus trichophyllus* Chaix var. *calvescens* W. B. Drew, *Rhodora*, 38 : 32. 1936

No collections from Michigan referable to this variety could be found in the state herbaria.

Reported from Keweenaw Co., Farwell 134 (*Rhodora*, 38 : 32. 1936).

4. *Ranunculus flabellaris* Raf.

R. delphinifolius Torr.

Quiet waters; apparently absent from the Upper Peninsula.

Specimens examined. — Washtenaw Co., Steinbach Woods, E. W. Erlanson 931. Ingham Co., near Lansing, C. F. Wheeler, June, 1895. Livingston Co., Marion Township, F. C. Blanchard, May, 1933. Oakland Co., Royal Oak, C. Billington, May, 1921. Macomb Co., Washington, D. Cooley, June, 1850. St. Clair Co., near Port Huron, C. K. Dodge, May, 1900. Gratiot Co., Alma, C. A. Davis, May, 1890. Emmet Co., Carp River, C. O. Erlanson 335.

Reported from: Kalamazoo Co., C. R. and F. N. Hanes, in 1936. Kent Co., Grand Rapids Township, Sister M. Marcelline Horton, in 1939.

4a. *Ranunculus flabellaris* Raf. f. *riparius* Fern., *Rhodora*, 38 : 171. 1936

R. delphinifolius Torr. var. *terrestris* of *Gray's New Manual*, Seventh Edition.

Rooting out of water.

Specimens examined. — Monroe Co., near Milan, B. M. Robertson 117. Macomb Co., Washington, D. Cooley, June, 1853. Ionia Co., Hubbardston, C. F. Wheeler, in 1870.

5. *Ranunculus Gmelini* DC. var. *Purshii* (Richards) Hara, *Rhodora*, 41 : 386. 1939

R. Purshii Richards.

Shallow pools, ditches, and on shores.

Specimens examined. — Ingham Co., Stockbridge, June, 1898. Gratiot Co., Alma, C. A. Davis, May, 1890. Alpena Co., near Alpena, C. F. Wheeler, July, 1895. Cheboygan Co., near Topinabee, J. H. Ehlers 3243, 3523. Delta Co., Chandler's Falls, C. F. Wheeler, Aug., 1892. Chippewa Co., near Vermilion, K. K. Mackenzie, June, 1914.

Reported from: Kent Co., near Grand Rapids, N. Coleman, in 1873. Emmet Co., Gates and Ehlers, in 1927. Gogebic Co., Gogebic Lake, H. T. Darlington, in 1920. Menominee Co., C. A. Davis, in 1908.

5a. *Ranunculus Gmelini* DC. var. *prolificus* (Fern.) Hara, *Rhodora,* 19 : 135. 1917; and 41 : 386. 1939

R. multifidus var. *terrestris* Gray.
R. Purshii var. *prolificus* Fern.

On muddy banks.

M. L. Fernald (*Rhodora,* 38 : 173. 1936) writes: "The type of *R. multifidus,* var. *terrestris* Gray belongs very definitely with *R. Purshii,* not with *R. flabellaris* and it is the upright paniculate-branched *R. Purshii,* var. *prolificus.*"

The type of *R. multifidus* var. *terrestris* was collected at Ann Arbor by Miss Clark (Gray Herbarium).

Specimens examined. — Ingham Co., East Lansing, C. F. Wheeler, Sept., 1894. Alpena Co., Alpena, C. F. Wheeler, Aug., 1895.

Reported from Washtenaw Co., Ann Arbor, Miss Clark (*Gray's Manual,* Fifth Edition, p. 41. 1867).

6. *Ranunculus ambigens* S. Wats. (*Rhodora,* 38 : 173. 1936)

R. laxicaulis (T. & G.) Darby.
R. obtusiusculus Raf.

Southern Michigan; rare and local.

Specimens examined. — St. Clair Co., C. K. Dodge, Aug., 1904; Algonac, W. S. Cooper, Aug., 1903.

7. *Ranunculus reptans* L.

R. Flammula L. var. *reptans* (L.) Mey.

Sandy or gravelly shores; not seen from the center of the state.

Specimens examined. — Muskegon Co., near Twin Lake, C. D. McLouth, July, 1899. Cheboygan Co., C. O. Erlanson 598.

Alger Co., K. K. Mackenzie, Aug., 1916. Keweenaw Co., Isle Royale, C. A. Brown 3471, 3523.

Reported from: Wayne Co., Belle Isle, O. A. Farwell. St. Clair Co., Algonac, W. S. Cooper. Delta Co., Escanaba, E. J. Hill, in 1885. Chippewa Co., Homestead, F. J. Hermann 7149.

7a. *Ranunculus reptans* L. var. *ovalis* (Bigel.) T. & G. (*Rhodora,* 19: 135. 1917)

Northern Michigan; in habitats similar to those of the species.

Specimens examined. — Cheboygan Co., Douglas Lake, J. H. Ehlers 8247. Ontonagon Co., Porcupine Mts., H. T. Darlington, Aug., 1923. Keweenaw Co., Bête Gris, F. J. Hermann 375.

8. *Ranunculus rhomboideus* Goldie. (*Rhodora,* 38:175–177. 1936)

? *R. ovalis* Raf.

Southern Michigan; prairies and dry hills; rare.

Specimens examined. — St. Clair Co., near Port Huron, C. K. Dodge, April, 1894. Kent Co., Grand Rapids, E. J. Cole, May, 1901.

Reported from: Washtenaw Co., Pittsfield Township, B. A. Walpole, in 1924. Ionia Co., Muir and Palo. "Prairies, Michigan," in *Gray's New Manual,* Seventh Edition.

9. *Ranunculus sceleratus* L.

Wet ditches and swamps; frequent.

Specimens examined. — Monroe Co., near Milan, B. M. Robertson 241. Washtenaw Co., Nichols Arboretum, F. J. Hermann 1134. Wayne Co., Detroit Zoo, J. M. Sutton 396. Ingham Co., Lansing. Oakland Co., Independence Township, B. F. Chandler, May, 1913. Ottawa Co., Holland, C. H. Kauffman, Aug., 1910. St. Clair Co., near Port Huron, C. K. Dodge, June, 1892. Muskegon Co., Muskegon, W. J. Beal, June, 1898. Gratiot Co., Alma, C. A. Davis, May, 1892. Saginaw Co., Laport Road, R. R. Dreisbach 4814. Grand Traverse Co., Williamsburg, J. H. Ehlers 3442. Emmet Co., Big Stone Bay, C. O. Erlanson 554. Cheboygan Co., J. H. Ehlers 3239, 3357, 5584. Houghton Co., Laurium, F. J. Hermann 275. Keweenaw Co., Isle Royale, J. B. McFarlin 2322.

Reported from: Kalamazoo Co., C. R. and F. N. Hanes, in

1936. Manistee Co., Manistee, F. P. Daniels, in 1903. Mackinac Co., Mackinac Is., C. K. Dodge, in 1913. Gogebic Co., introduced at Ironwood, H. T. Darlington, in 1920.

10. *Ranunculus abortivus* L.

Many segregates from *R. abortivus* have been proposed as species, particularly by E. L. Greene, but in Michigan none of these appears to have characters of sufficient constancy to be of taxonomic significance.

Shady hillsides and along brooks; common.

Specimens examined. — Berrien Co., near Niles, B. M. Robertson 93. Monroe Co., near Milan, B. M. Robertson 67. Kalamazoo Co., Kalamazoo, R. M. Gibbs, May, 1877. Washtenaw Co., Speechley's Woods, E. W. Erlanson 951. Allegan Co., Swan Creek Experiment Station, F. W. Stuewer 170. Ingham Co., East Lansing, L. J. Cole, May, 1895. Livingston Co., Patterson Lake, C. O. Erlanson 58. Macomb Co., Washington, D. Cooley, May, 1849. Kent Co., H. M. Bailey, May, 1891. St. Clair Co., near Port Huron, C. K. Dodge, May, 1892. Gratiot Co., near Alma, C. A. Davis, May, 1888. Cheboygan Co., near Mud Lake, J. H. Ehlers 3366. Marquette Co., B. Barlow, May, 1901.

Reported from: St. Joseph Co., near Sturgis, F. P. Daniels, in 1903. Oakland Co., Parkedale Farm, O. A. Farwell, in 1913. Saginaw Co., Maple Grove Township, Sister M. Marcelline Horton, in 1925. Isabella Co., Mt. Pleasant, C. A. Davis, in 1888. Huron Co., Charity Is., C. K. Dodge, in 1911. Manistee Co., Manistee, F. P. Daniels, in 1903. Mackinac Co., Mackinac Is., C. K. Dodge, in 1913. Gogebic Co., H. T. Darlington, in 1920. Ontonagon Co., Porcupine Mts., H. T. Darlington.

10a. *Ranunculus abortivus* L. var. *acrolasius* Fern., *Rhodora*, 40 : 417. 1938

Swamps and bogs.

Specimens examined. — Wayne Co., Detroit Zoo, J. M. Sutton 396. Wexford Co., Harrietta, H. C. Skeels, May, 1895. Cheboygan Co., Douglas Lake, C. O. Erlanson 280. Houghton Co., Laurium, F. J. Hermann 245. Keweenaw Co., Copper Harbor, F. J. Hermann 7688.

10b. *Ranunculus abortivus* L. var. *eucyclus* Fern.

R. michiganensis Farwell.

Specimens examined. Berrien Co., C. Billington, May, 1921. Washtenaw Co., near Ann Arbor, C. O. Erlanson 17. Oakland Co., Independence Township, B. F. Chandler, May, 1913.

11. *Ranunculus recurvatus* Poir.

Woods and swamps; common.

Specimens examined. — Berrien Co., near Niles, B. M. Robertson 95. Cass Co., Cassopolis, C. F. Wheeler, June, 1890. Van Buren Co., Keeler, H. S. Pepoon, May, 1906. Calhoun Co., B. M. Robertson 182. Washtenaw Co., Steinbach Woods, E. W. Erlanson 920. Wayne Co., Linden Park, G. Suttie, June, 1893. Ingham Co., East Lansing, H. C. Skeels, May, 1894. Macomb Co., Washington, D. Cooley, May, 1829. Kent Co., near Grand Rapids, H. M. Bailey, in 1891. Shiawassee Co., Owosso, G. H. Hicks, May, 1889. St. Clair Co., C. K. Dodge, June, 1913. Gratiot Co., Alma, C. A. Davis, May, 1888. Saginaw Co., R. R. Dreisbach, June, 1931. Benzie Co., Inland, June, 1888. Antrim Co., C. Leavitt, May, 1891. Emmet Co., J. H. Ehlers 1200. Cheboygan Co., Douglas Lake, J. H. Ehlers 3359. Marquette Co., B. Barlow, June, 1901. Gogebic Co., Slate River, H. T. Darlington, Aug., 1919. Houghton Co., near Lake Linden, F. J. Hermann 457.

Reported from: Kalamazoo Co., C. R. and F. N. Hanes, in 1936. Oakland Co., Parkedale Farm, O. A. Farwell, in 1913. Huron Co., Charity Is., C. K. Dodge, in 1911. Newaygo Co., north of Bridgeton, F. J. Hermann 8611. Mackinac Co., Mackinac Is., C. K. Dodge, in 1913. Manistee Co., Manistee, F. P. Daniels, in 1903. Ontonagon Co., Porcupine Mts., H. T. Darlington. Keweenaw Co., south of Cliff, F. J. Hermann 7649.

12. *Ranunculus fascicularis* Muhl.

Dry or moist hills; frequent in the southern counties, rare in the Upper Peninsula.

Specimens examined. — Hillsdale Co., near Moscow, B. M. Robertson 85. Washtenaw Co., Lima Township, J. H. Ehlers 1874. Allegan Co., Swan Creek Experiment Station, A. O. Haugen 62. Oakland Co., Bloomfield Township, B. F. Chandler, June, 1913.

Kent Co., Grand Rapids, D. S. Bailey, May, 1892. St. Clair Co., near Roberts Landing, C. K. Dodge, May, 1910. Marquette Co., Huron Mt., C. K. Dodge, June, 1917.

Reported from: Berrien Co., H. S. Pepoon. Cass Co., Sister M. Marcelline Horton, in 1916. St. Joseph Co., Sturgis, F. P. Daniels, in 1903. Kalamazoo Co., C. R. and F. N. Hanes, in 1936. Saginaw Co., Maple Grove Township, Sister M. Marcelline Horton, in 1939.

13. *Ranunculus hispidus* Michx.

Southern Michigan; moist places, chiefly woods.

Specimen examined. — Wayne Co., Eight-Mile Road, J. M. Sutton, May, 1913.

Reported from: Kalamazoo Co., C. R. and F. N. Hanes, in 1936. Kent Co., Walker Township, Sister M. Marcelline Horton, in 1939. Washtenaw Co., Ypsilanti Township, B. A. Walpole, in 1924. Iosco Co., Sister M. Marcelline Horton, in 1930. Cheboygan Co., Gates and Ehlers, in 1924.

13a. *Ranunculus hispidus* Michx. var. *falsus* Fern., *Rhodora*, 22 : 30. 1920

Range and habitat apparently those of the species.

Specimens examined. — Allegan Co., Swan Creek Experiment Station, A. O. Haugen 142. Ingham Co., East Lansing, L. J. Cole, May, 1895. Kalamazoo Co., Climax Township, C. R. Hanes, in 1939. Kent Co., Grand Rapids, H. C. Skeels, May, 1895.

14. *Ranunculus septentrionalis* Poir.

R. caricetorum Greene.

Moist or shady places.

Specimens examined. — Berrien Co., Warren Woods, C. Billington, May, 1920. Hillsdale Co., Hillsdale, D. A. Pelton, May, 1885. Van Buren Co., Keeler, H. S. Pepoon, May, 1906. Jackson Co., S. H. and D. R. Camp, May, 1893. Washtenaw Co., Cedar Bend, J. H. Ehlers 670. Wayne Co., B. F. Chandler, May, 1913. Macomb Co., Washington, D. Cooley, May, 1843. Ionia Co., Hubbardston, C. F. Wheeler, June, 1890. St. Clair Co., Port Huron, C. K. Dodge, May, 1892. Gratiot Co., Alma, C. A. Davis, May, 1891. Cheboygan Co., Burt Lake, J. H. Ehlers 43. Chippewa Co., C. K. Dodge, June, 1914. Keweenaw Co., Copper Harbor, F. J. Hermann 7788.

Reported from: St. Joseph Co., Sturgis, F. P. Daniels, in 1903. Kalamazoo Co., C. R. and F. N. Hanes, in 1936. Kent Co., Plaster Creek, Sister M. Marcelline Horton. Saginaw Co., Maple Grove Township, Sister M. Marcelline Horton, in 1939. Manistee Co., Manistee, F. P. Daniels, in 1903. Gogebic Co., H. T. Darlington, in 1920.

15. *Ranunculus repens* L.

Waste places; local.

Specimens examined. — St. Clair Co., Port Huron, C. K. Dodge, Sept., 1896. Cheboygan Co., J. H. Ehlers 4640 (small specimen with pubescence appressed; flowers 1.5 cm. wide).

Reported from: Kalamazoo Co., C. R. and F. N. Hanes, in 1936. Washtenaw Co., Ypsilanti, B. A. Walpole, in 1924. Oakland Co., Rochester, W. A. Brotherton and O. A. Farwell. Manistee Co., Manistee, F. P. Daniels, in 1903. Keweenaw Co., Montreal River, O. A. Farwell.

15a. *Ranunculus repens* L. var. *villosus* Lamotte. (*Conn. Geol. and Nat. Hist. Surv.*, Bull. No. 48 : 47. 1930)

Specimens examined. — St. Clair Co., Port Huron, C. K. Dodge, June, 1897. Cheboygan Co., J. H. Ehlers 3531, 3639. Gogebic Co., Slate River, H. T. Darlington, Aug., 1919. Ontonagon Co., Porcupine Mts., H. T. Darlington, Aug., 1923.

15b. *Ranunculus repens* L. var. *erectus* DC. (*Conn. Geol. and Nat. Hist. Surv.*, Bull. No. 48 : 47. 1930)

Specimens examined. — Washtenaw Co., Lewis Foote, May, 1863. Shiawassee Co., Owosso, G. H. Hicks, April, 1889. St. Clair Co., Port Huron, C. K. Dodge, July, 1898. Gratiot Co., Alma, C. A. Davis, May, 1888. Oscoda Co., Comins, June, 1888.

16. *Ranunculus pennsylvanicus* L. f.

Wet places; frequent.

Specimens examined. — Cass Co., Silver Creek, H. S. Pepoon, Aug., 1905. Van Buren Co., Aug., 1838. Washtenaw Co., Forestry Farm, E. W. Erlanson 5371. Wayne Co., Belle Isle, H. H. Rush, Aug., 1884. Eaton Co., near Grand Ledge, B. M. Robertson 341. Ingham Co., East Lansing, L. J. Cole, Aug., 1895. Livingston Co.,

Whitmore Lake, J. Dawson. Oakland Co., Royal Oak Township, B. F. Chandler, July, 1916. Macomb Co., Washington, D. Cooley, Aug., 1840. Ottawa Co., Holland, L. H. Pennington, Aug., 1910. Kent Co., Grand Rapids, H. M. Bailey, July, 1891. Shiawassee Co., Owosso, G. H. Hicks, July, 1889. Genesee Co., Flint, D. Clark 951. Gratiot Co., Alma, C. A. Davis, July, 1889. Clare Co., Farwell, H. T. Darlington, Aug., 1916. Roscommon Co., Bessey and Darlington, July, 1916. Grand Traverse Co., Green Lake Township, June, 1888. Emmet Co., Pellston, J. H. Ehlers 1024. Cheboygan Co., Douglas Lake, C. O. Erlanson 546. Chippewa Co., Prentis Bay, J. H. Ehlers 1359. Marquette Co., near Big Bay, K. K. Mackenzie, July, 1916. Ontonagon Co., Porcupine Mts., H. T. Darlington, Aug., 1923. Houghton Co., Bear Lake, F. J. Hermann 665. Keweenaw Co., Clifton, O. A. Farwell, Aug., 1888.

Reported from: Kalamazoo Co., C. R. and F. N. Hanes, in 1936. Saginaw Co., Sister M. Marcelline Horton, in 1924. Huron Co., Charity Is., C. K. Dodge, in 1911. Luce Co., shore of Lake Manistique, F. J. Hermann 8307. Gogebic Co., Cisco Lake, H. T. Darlington, in 1920.

17. *Ranunculus acris* L.

Moist meadows; generally local and infrequent in the south, abundant in the Upper Peninsula.

Specimens examined. — Washtenaw Co., E. W. Erlanson 137. Wayne Co., Lewis Foote, June, 1870. Allegan Co., Swan Creek Experiment Station, F. W. Stuewer 135. Ingham Co., East Lansing, H. C. Skeels, June, 1894. Ottawa Co., Holland, C. H. Kauffman, Aug., 1910. Kent Co., W. E. Mulliken, Aug., 1897. St. Clair Co., Grant Township, C. K. Dodge, May, 1911. Cheboygan Co., J. H. Ehlers 357, 6047. Mackinac Co., Prentis Bay, J. H. Ehlers 1449. Chippewa Co., Whitefish Point, C. Billington, Aug., 1923. Marquette Co., A. Dachnowski and C. A. Davis, July, 1906. Gogebic Co., H. T. Darlington, June, 1920. Houghton Co., Laurium, F. J. Hermann 236, 597.

Reported from: Van Buren Co., South Haven, W. J. Beal, in 1904. Kalamazoo Co., C. R. and F. N. Hanes, in 1936. Eaton Co., near Bellevue, I. H. Hall, in 1870. Macomb Co., W. J. Beal, in 1904. Genesee Co., Flint, W. J. Beal, in 1904. Saginaw Co., Chesaning Township, Sister M. Marcelline Horton, in 1925. Charle-

voix Co., Sister M. Marcelline Horton, in 1933. Keweenaw Co., Isle Royale, McCargoe Cove, A. H. W. Povah, in 1934.

2. THALICTRUM [Tourn.] L.

a. Leaflets suborbicular
  b. Achenes thick-walled; leaflets glandular-pruinose, glaucous beneath, coarsely toothed; estival . . . . 1. *T. confine*
  b. Achenes thin-walled; leaflets thin, light green, glabrous, usually 5–7-lobed; vernal . . . . 2. *T. dioicum*
a. Leaflets oblong, more or less pubescent, usually 3-toothed; estival 3. *T. dasycarpum*

1. *Thalictrum confine* Fern.

Glades and openings in thicket bordering calcareous beach of Lake Michigan.

Specimen examined. — Schoolcraft Co., east of Manistique, M. L. Fernald and A. S. Pease 3306.

2. *Thalictrum dioicum* L.

Rich or rocky woods; common.

Specimens examined. — Berrien Co., Warren Woods, C. Billington, May, 1921. Cass Co., near Lime Lake, B. M. Robertson 206. Hillsdale Co., near Moscow, B. M. Robertson 86. Lenawee Co., near Clinton, B. M. Robertson 77. Monroe Co., near Milan, B. M. Robertson 73. Washtenaw Co., southwest of Platt, E. W. Erlanson and F. J. Hermann 5009. Oakland Co., Addison Township, C. Billington, June, 1924. Kent Co., Grand Rapids, H. M. Bailey, May, 1892. St. Clair Co., Port Huron, C. K. Dodge, May, 1901. Gratiot Co., Alma, C. A. Davis, May, 1888. Cheboygan Co., Douglas Lake, J. H. Ehlers 1591, 1603. Ontonagon Co., Porcupine Mts., H. T. Darlington, Aug., 1923.

Reported from: St. Joseph Co., Sturgis, F. P. Daniels, in 1903. Kalamazoo Co., C. R. and F. N. Hanes, in 1936. Ottawa Co., Tallmadge Township, C. W. Bazuin, in 1939. Saginaw Co., Maple Grove Township, Sister M. Marcelline Horton, in 1939. Isabella Co., Mt. Pleasant, C. A. Davis, in 1888. Huron Co., Charity Is., C. K. Dodge, in 1911. Manistee Co., Manistee, F. P. Daniels, in 1903. Gogebic Co., near Bass Lake, H. T. Darlington, in 1920. Lenawee Co., Adrian, F. L. Stearns, in 1905.

3. *Thalictrum dasycarpum* Fisch. & Lall.

T. purpurascens of American authors, not L.

Rich damp open ground, generally on banks of lakes and rivers or in swamps and bogs.

Specimens examined. — Monroe Co., near Milan, B. M. Robertson 136. Washtenaw Co., north bank Huron River, E. W. Erlanson 138, 5189. Wayne Co., Detroit Zoo, J. M. Sutton, July, 1916. Eaton Co., near Grand Ledge, B. M. Robertson 341. Oakland Co., C. Billington, July, 1916. St. Clair Co., near Port Huron, C. K. Dodge, July, 1914. Gratiot Co., Alma, C. A. Davis, June, 1891. Cheboygan Co., Maple River, J. H. Ehlers 536. Mackinac Co., banks of Brevort River, J. H. Ehlers 4556. Chippewa Co., Prentis Bay, C. O. Erlanson 740. Ontonagon Co., Porcupine Mts., H. T. Darlington, Aug., 1923.

Reported from: Kalamazoo Co., north of Vicksburg, F. J. Hermann 9012. Kent Co., Plainfield Township, C. W. Bazuin, in 1939. Isabella Co., Mt. Pleasant, C. A. Davis, in 1888. Huron Co., Charity Is., C. K. Dodge, in 1911. Mackinac Co., Mackinac Is., C. K. Dodge, in 1913. Gogebic Co., H. T. Darlington, in 1920. Houghton Co., near Lake Linden, F. J. Hermann 441. Keweenaw Co., marsh near Cliff, F. J. Hermann 8052.

3. ANEMONELLA Spach.

Anemonella thalictroides (L.) Spach.

Syndesmon thalictroides (L.) Hoffmg.

Woods; probably restricted, in Michigan, to the southern half of the Lower Peninsula.

Specimens examined. — Berrien Co., near Niles, B. M. Robertson 101. St. Joseph Co., near White Pigeon, B. M. Robertson 92. Lenawee Co., near Clinton, B. M. Robertson 75. Van Buren Co., Magician Lake, H. S. Pepoon, May, 1903. Washtenaw Co., White's Woods, F. J. Hermann 51. Ingham Co., East Lansing, H. C. Skeels, April, 1894. Livingston Co., E. S. George Reserve, J. H. Ehlers 5037. Oakland Co., Farmington Township, B. F. Chandler, May, 1916. Kent Co., Grand Rapids, H. M. Bailey, May, 1892.

Reported from Kalamazoo Co., C. R. and F. N. Hanes, in 1936. Keweenaw Co., O. A. Farwell (Beal, *Michigan Flora*).

4. ANEMONE [Tourn.] L.

a. Achenes densely woolly
  b. Sepals red .... 1. *A. multifida* var. *hudsoniana* f. *sanguinea*
  b. Sepals greenish white
    c. Head of fruit cylindrical; divisions of cauline leaves 3–5 cm. long, cleft into rather narrow segments; sepals rather obtuse 2. *A. cylindrica*
    c. Head of fruit ovoid; divisions of cauline leaves 6–10 cm. long, much less finely cleft; sepals acute .... 3. *A. virginiana*
a. Achenes pubescent or naked
  b. Involucral leaves sessile; plant tall, over 20 cm. high; flowers several .... 4. *A. canadensis*
  b. Involucral leaves long-petioled, trifoliolate; plant low, less than 20 cm. high; flowers solitary .... 5. *A. quinquefolia* var. *interior*

1. *Anemone multifida* Poir. var. *hudsoniana* DC. f. *sanguinea* (Pursh) Fern., *Rhodora*, 19 : 141. 1917

A. hudsoniana Richards.

Plentiful along sandy shores or dunes of the Great Lakes.

Specimens examined. — Benzie Co., near South Frankfort, W. A. Weir, June, 1893. Leelanau Co., Sleeping Bear Point, J. H. Ehlers 4024. Presque Isle Co., near Rogers City, C. K. Dodge, Sept., 1913. Emmet Co., Big Stone Bay, J. H. Ehlers 3399. Cheboygan Co., Bois Blanc Is., C. Billington, Aug., 1916. Alpena Co., near Alpena, C. K. Dodge, July, 1912. Mackinac Co., Prentis Bay, J. H. Ehlers 2977. Keweenaw Co., Isle Royale, A. E. Foote, in 1869.

Reported from: Tuscola Co., C. A. Davis, in 1904. Bay Co., C. A. Davis, in 1904. Iosco Co., Au Sable River, Sister M. Marcelline Horton, in 1939. Antrim Co., Torch Lake, E. J. Hill, in 1881. Charlevoix Co., Beaver Is., Sister M. Marcelline Horton, in 1939.

2. *Anemone cylindrica* Gray

Sandy soil and rocky woods.

Specimens examined. — Berrien Co., Niles, July, 1867. Monroe Co., Monroe. Van Buren Co., Keeler, H. S. Pepoon, Aug., 1905. Washtenaw Co., Ann Arbor, C. D. LaRue, July, 1915. Wayne Co., Detroit Zoo, J. M. Sutton 401. Ingham Co., Lake Lansing, July, 1888. Oakland Co., Avon Township, C. Billington, July, 1918. Kent Co., Grand Rapids, H. M. Bailey, July, 1893.

Ionia Co., Hubbardston, C. F. Wheeler. St. Clair Co., near Port Huron, July, 1906. Muskegon Co., W. J. Beal, June, 1898. Newaygo Co., Hess Lake, H. T. Darlington, Aug., 1916. Montcalm Co., Greenville, B. Barlow, Sept., 1900. Huron Co., Hume Township, C. A. Davis, June, 1896. Lake Co., Baldwin, July, 1888. Arenac Co., near Omer, C. F. Wheeler, Aug., 1900. Iosco Co., East Tawas, H. H. Bartlett, July, 1928. Alpena Co., Alpena, C. A. Davis, June, 1891. Cheboygan Co., Douglas Lake, J. H. Ehlers 941. Presque Isle Co., Rogers City, F. J. Hermann 1213. Delta Co., north of Garden, M. L. Fernald and A. S. Pease 3308. Mackinac Co., Scotty Bay, C. O. Erlanson 770.

Reported from: St. Joseph Co., Sturgis, F. P. Daniels, in 1902. Kalamazoo Co., C. R. and F. N. Hanes, in 1936. Manistee Co., Manistee, F. P. Daniels, in 1903. Emmet Co., Gates and Ehlers, in 1924.

3. *Anemone virginiana* L.

Woods and meadows; frequent.

Specimens examined. — Berrien Co., near Birchwood Beach, C. K. Dodge, Aug., 1917. Monroe Co., Milan, B. M. Robertson 310. Van Buren Co., Keeler, H. S. Pepoon. Jackson Co., Francisco, C. H. Kauffman and B. B. Kanouse, Aug., 1923. Washtenaw Co., near Ann Arbor, F. J. Hermann 1235. Wayne Co., Dearborn Township, C. Billington, July, 1917. Allegan Co., Swan Creek Experiment Station, A. O. Haugen 196. Eaton Co., near Grand Ledge, B. M. Robertson 349. Ingham Co., E. Lansing, H. C. Skeels, July, 1894. Oakland Co., Rochester, O. A. Farwell 6960. Macomb Co., Washington, D. Cooley, July, 1847. Ottawa Co., Holland, C. H. Kauffman, Aug., 1910. Kent Co., Grand Rapids, H. M. Bailey, July, 1893. Ionia Co., Hubbardston, C. F. Wheeler, June, 1890. Shiawassee Co., Owosso, G. H. Hicks, July, 1889. St. Clair Co., Port Huron, C. K. Dodge, July, 1895. Montcalm Co., Crystal Lake, C. F. Wheeler, July, 1900. Gratiot Co., Alma, C. A. Davis, June, 1890. Oscoda Co., W. J. Beal and C. F. Wheeler, July, 1888. Alpena Co., Thunder Bay, J. H. Ehlers 3168. Emmet Co., Cecil Bay, J. H. Ehlers 2176. Cheboygan Co., Burt Lake, J. H. Ehlers 2057. Gogebic Co., near Watersmeet, H. T. Darlington, Aug., 1919.

Reported from: St. Joseph Co., Sturgis, F. P. Daniels, in 1903.

Kalamazoo Co., C. R. and F. N. Hanes, in 1936. Huron Co., Charity Is., C. K. Dodge, in 1911. Manistee Co., Manistee, C. K. Dodge, in 1913.

4. *Anemone canadensis* L.

Along stream banks; common.

Specimens examined. — Monroe Co., near Monroe, B. M. Robertson 137. Van Buren Co., South Haven, L. H. Pennington, July, 1910. Washtenaw Co., Huron River at Ypsilanti, B. A. Walpole, May, 1918. Allegan Co., Swan Creek Experiment Station, F. W. Stuewer 215. Eaton Co., near Grand Ledge, B. M. Robertson 350. Ingham Co., East Lansing, H. T. Darlington, June, 1916. Kent Co., Grand Rapids, H. M. Bailey, June, 1891. St. Clair Co., Port Huron, C. K. Dodge, June, 1892. Muskegon Co., W. J. Beal, June, 1898. Gratiot Co., Alma, C. A. Davis, June, 1889. Midland Co., near Midland, R. R. Dreisbach, July, 1927. Chippewa Co., Prentis Bay, C. O. Erlanson 738. Cheboygan Co., Burt Lake, C. O. Erlanson 202. Marquette Co., B. Barlow, July, 1901. Gogebic Co., Watersmeet, H. T. Darlington, Aug., 1919. Houghton Co., Bear Lake, F. J. Hermann 666. Keweenaw Co., Copper Harbor, F. J. Hermann 505.

Reported from: St. Joseph Co., Sturgis, F. P. Daniels, in 1903. Kalamazoo Co., C. R. and F. N. Hanes, in 1936. Oakland Co., Parkedale Farm, O. A. Farwell, in 1913. Ottawa Co., Grand Haven Township, Sister M. Marcelline Horton, in 1939. Saginaw Co., Maple Grove Township, Sister M. Marcelline Horton, in 1934. Arenac Co., Rifle River, Sister M. Marcelline Horton, in 1926. Manistee Co., Manistee, F. P. Daniels, in 1904. Emmet Co., Gates and Ehlers, in 1924. Mackinac Co., Mackinac Is., C. K. Dodge, in 1913. Ontonagon Co., Porcupine Mts., H. T. Darlington.

5. *Anemone quinquefolia* L. var. *interior* Fern., *Rhodora,* 37 : 260. 1935

"Nearly all material of *A. quinquefolia* from the Great Lakes region north to James Bay has the stem of the flowering plants spreading-villous as are the petioles of the leaves of the 1-leaved young plants and often the petioles of the involucral leaves and

the peduncles of the flowers. Var. *interior* is, then, a well-defined inland variety . . . " (M. L. Fernald, *loc. cit.*).

In the study of herbarium material for this paper no Michigan collections of the glabrous typical *A. quinquefolia* were found.

Margins of woods; common.

Specimens examined. — Berrien Co., Paris, H. M. Bailey, May, 1891. Cass Co., H. S. Pepoon, May, 1905. Hillsdale Co., near Moscow, B. M. Robertson 87. Monroe Co., near Milan, B. M. Robertson 61. Kalamazoo Co., Kalamazoo, R. M. Gibbs, May, 1877. Washtenaw Co., south of Ann Arbor, C. O. Erlanson 25. Wayne Co., Detroit Zoo, J. M. Sutton 402. Allegan Co., Swan Creek Experiment Station, F. W. Stuewer 185. Ingham Co., East Lansing, L. J. Cole, May, 1895. Oakland Co., Rochester, O. A. Farwell 7711. Kent Co., Grand Rapids, H. C. Skeels, May, 1895. Ionia Co., Hubbardston, C. F. Wheeler, June, 1890. St. Clair Co., near Port Huron, C. K. Dodge, May, 1892. Gratiot Co., Alma, C. A. Davis, May, 1892. Iosco Co., Au Sable River, J. H. Ehlers 4767. Crawford Co., near Grayling, June, 1888. Marquette Co., near Humboldt, M. L. Fernald and A. S. Pease 3310. Houghton Co., Laurium, F. J. Hermann 272. Keweenaw Co., O. A. Farwell, June, 1888; Isle Royale, A. E. Foote, in 1868.

Reported from: St. Joseph Co., Sturgis, F. P. Daniels, in 1903. Saginaw Co., Sister M. Marcelline Horton, in 1925. Bay Co., G. M. Bradford. Emmet Co., near Pellston, A. Sharp. Manistee Co., Manistee, F. P. Daniels, in 1903. Mackinac Co., Mackinac Is., C. K. Dodge, in 1913. Gogebic Co., Bessemer-Ironwood region, H. T. Darlington, in 1920. Ontonagon Co., Porcupine Mts., H. T. Darlington.

5. HEPATICA [RUPP.] HILL

a. Involucral bracts and lobes of leaves obtuse .... 1. *H. americana*
a. Involucral bracts and lobes of leaves acute .... 2. *H. acutiloba*

1. *Hepatica americana* (DC.) Ker. (*Rhodora*, 19 : 14. 1917)

H. triloba of American authors, not Chaix.
H. Hepatica of American authors, not Karst.

Common in woods and on wooded dunes.

Flowers normally blue. The white-flowered form is f. *candida* Fern.; the pink-flowered, f. *rhodantha* Fern. (*Rhodora*, 19 : 45. 1917).

Specimens examined. — Berrien Co., J. Colvin 1060. Hillsdale Co., Hillsdale, D. A. Pelton, May, 1885. Cass Co., near Jones, B. M. Robertson 210. Washtenaw Co., Ann Arbor, G. W. Allyn, May, 1873. Wayne Co., Dearborn, B. F. Chandler, Oct., 1916. Allegan Co., Swan Creek Experiment Station, A. O. Haugen 61. Macomb Co., Washington, D. Cooley, Aug., 1900. Kent Co., Grand Rapids, H. M. Bailey, May, 1891. St. Clair Co., near Port Huron, C. K. Dodge, May, 1892. Muskegon Co., Lake Michigan, E. A. Bessey, Aug., 1916. Gratiot Co., near Alma, C. A. Davis, April, 1892. Midland Co., one mile west of Averill, R. R. Dreisbach 4702. Calhoun Co., Marshall, W. J. Beal, Aug., 1898. Oscoda Co., W. J. Beal and C. J. Wheeler, July, 1888. Cheboygan Co., Douglas Lake, J. H. Ehlers 2335. Alger Co., Chatham, C. F. Wheeler, Aug., 1900. Gogebic Co., Gogebic Lake, H. T. Darlington, Aug., 1919. Keweenaw Co., Copper Harbor, F. J. Hermann 220.

Reported from: St. Joseph Co., Sturgis, F. P. Daniels, in 1903. Lenawee Co., Adrian, F. L. Stearns, in 1905. Kalamazoo Co., C. R. and F. N. Hanes, in 1936. Jackson Co., G. H. Hicks, in 1893. Ottawa Co., Tallmadge Township, C. W. Bazuin, in 1939. Huron Co., Charity Is., C. K. Dodge, in 1911. Manistee Co., Manistee, F. P. Daniels, in 1903. Emmet Co., Gates and Ehlers, in 1924. Ontonagon Co., Porcupine Mts., H. T. Darlington. Mackinac Co., Mackinac Is., C. K. Dodge, in 1913.

2. *Hepatica acutiloba* DC.

H. acuta (Pursh) Britton.

Common in beech and maple woods.

Specimens examined. — Berrien Co., Warren Woods, C. Billington, July, 1919. Cass Co., Magician Lake, H. S. Pepoon 663. Hillsdale Co., Hillsdale, D. A. Pelton, May, 1885. Washtenaw Co., five miles south of Ann Arbor, C. O. Erlanson 960. Wayne Co., Greenfield Township, B. F. Chandler, April, 1916. Ingham Co., East Lansing, H. C. Skeels, April, 1894. Kent Co., Grand Rapids, H. M. Bailey, May, 1892. Shiawassee Co., Owosso, G. H. Hicks, April, 1889. St. Clair Co., near Port Huron, C. K. Dodge, April, 1896. Gratiot Co., Alma, C. A. Davis, April, 1888. Wexford Co., Harrietta, H. C. Skeels, May, 1895. Otsego Co., near Vanderbilt, E. A. Bessey, July, 1912. Ontonagon Co., Porcupine Mts., H. T. Darlington, Aug., 1923.

Reported from: Kalamazoo Co., C. R. and F. N. Hanes, in 1936. Oceana Co., Weare Township, Sister M. Marcelline Horton, in 1917. Huron Co., Charity Is., C. K. Dodge, in 1911. Newaygo Co., Fremont Lake, F. J. Hermann 8685. Manistee Co., Manistee, F. P. Daniels, in 1903. Cheboygan Co., near Mackinac City, O. A. Farwell, in 1896. Mackinac Co., Mackinac Is., C. K. Dodge, in 1913.

6. CLEMATIS L.

a. Flowers white, 2 cm. in diameter, in leafy panicles .... 1. *C. virginiana*
a. Flowers purplish, 5–7.5 cm. in diameter, solitary in the axils or at the ends of the branches .... 2. *C. verticillaris*

1. *Clematis virginiana* L.

Low woods; frequent.

Specimens examined. — Berrien Co., Warren Woods, C. Billington, July, 1919. Cass Co., Dowagiac Swamp, F. C. Gates, Aug., 1906. St. Joseph Co., White Pigeon, Aug. Branch Co., July 27 (1838?). Washtenaw Co., Ann Arbor along Huron River, E. C. Almendinger, Aug., 1861. Ingham Co., East Lansing, H. C. Skeels, Oct., 1894. Macomb Co., Washington, D. Cooley, May, 1843. Ottawa Co., Holland, L. H. Pennington, Aug., 1910. Kent Co., Grand Rapids, H. M. Bailey, July, 1891. St. Clair Co., near Port Huron, C. K. Dodge, Aug., 1896. Gratiot Co., Alma, C. A. Davis, Aug., 1889. Missaukee Co., Bessey and Darlington, Aug., 1916. Roscommon Co., Higgins Lake, H. T. Darlington, July, 1916. Emmet Co., Maple River, J. H. Ehlers 609. Cheboygan Co., Lancaster Lake, J. H. Ehlers 1685. Mackinac Co., Bois Blanc Is., J. H. Ehlers 5135. Marquette Co., B. Barlow, July, 1901. Gogebic Co., State Line to Watersmeet, H. T. Darlington, Aug., 1919. Ontonagon Co., Porcupine Mts., H. T. Darlington, July, 1922. Keweenaw Co., near Silver Isle, F. J. Hermann 718.

Reported from: Kalamazoo Co., C. R. and F. N. Hanes, in 1936. Oakland Co., Parkedale Farm, O. A. Farwell, in 1913. Manistee Co., Manistee, F. P. Daniels, in 1903.

2. *Clematis verticillaris* DC.

Atragene americana Sims.

In Michigan apparently restricted to the Upper Peninsula; rocky hills; rare.

Specimens examined. — Iron Co., near Crystal Falls, C. A. Davis, Aug., 1905. Keweenaw Co., Isle Royale, C. A. Brown 3223, 3298, 3313.

Reported from Dickinson Co., Norway, S. M. Tobey.

7. ISOPYRUM L.

Isopyrum biternatum (Raf.) T. & G.

Locally common in beech and maple woods in the southern half of the Lower Peninsula.

Specimens examined. — Berrien Co., C. Billington, May, 1921. Van Buren Co., H. S. Pepoon, June, 1906. Kalamazoo Co., Kalamazoo, G. B. Sudworth, April, 1877. Washtenaw Co., Lodi, V. M. Spalding, May, 1892. Wayne Co., Plymouth, E. H. Ryder, May, 1898. Eaton Co., Bellevue, E. C. Almendinger. Ingham Co., East Lansing, H. C. Skeels, May, 1894. Kent Co., Grand Rapids, H. M. Bailey, May, 1891. Ionia Co., Hubbardston, C. F. Wheeler, May, 1876. Shiawassee Co., Owosso, G. H. Hicks, April, 1889. Gratiot Co., Alma, C. A. Davis, May, 1888.

Reported from: Ottawa Co., Tallmadge Township, Sister M. Marcelline Horton, in 1919. Saginaw Co., Maple Grove Township, Sister M. Marcelline Horton, in 1939.

8. CALTHA [Rupp.] L.

Caltha palustris L.

In swamps; very common.

Specimens examined. — Berrien Co., near Niles, B. M. Robertson 100. Cass Co., near Lime Lake, B. M. Robertson 197. Washtenaw Co., near Ypsilanti, B. A. Walpole, March, 1918. Wayne Co., Detroit, J. M. Sutton, May, 1916. Allegan Co., Swan Creek Experiment Station, A. O. Haugen 73. Kent Co., Grand Rapids, H. M. Bailey, April, 1892. Ionia Co., Hubbardston, C. F. Wheeler. St. Clair Co., near Port Huron, C. K. Dodge, May, 1895. Gratiot Co., Alma, C. A. Davis, May, 1891. Bay Co., Kowkaulin, R. R. Dreisbach 4686. Clare Co., near Dodge, R. R. Dreisbach 4677. Cheboygan Co., Carp Creek, J. H. Ehlers 885. Houghton Co., F. J. Hermann 189.

Reported from: St. Joseph Co., Sturgis, F. P. Daniels, in 1903. Kalamazoo Co., C. R. and F. N. Hanes, in 1936. Oakland Co., Parkedale Farm, O. A. Farwell, in 1913. Manistee Co., Manistee, F. P. Daniels, in 1903. Wexford Co., Harrietta, H. C. Skeels, in 1896. Emmet Co., Gates and Ehlers, in 1924. Mackinac Co., Mackinac Is., C. K. Dodge, in 1913. Gogebic Co., H. T. Darlington, in 1920. Ontonagon Co., Porcupine Mts., H. T. Darlington.

9. AQUILEGIA [TOURN.] L.

Aquilegia canadensis L.

Open or rocky woods; frequent.

Specimens examined. — Berrien Co., C. Billington, May, 1921. Cass Co., Cassopolis, C. F. Wheeler, in 1890. Washtenaw Co., Ann Arbor, A. J. Pieters, June, 1893. Wayne Co., Detroit Zoo, J. M. Sutton, May, 1916. Allegan Co., Swan Creek Experiment Station, A. O. Haugen 130. Ingham Co., Lansing, F. L. Sleeper, June, 1866. Livingston Co., Strawberry Lake, J. H. Ehlers 1893. Oakland Co., Birmingham, J. M. Sutton, May, 1913. Kent Co., South Grand Rapids, G. Fyfe and J. Shaddick, May, 1895. Ionia Co., Hubbardston, C. F. Wheeler. Lapeer Co., south of Lapeer, C. K. Dodge, May, 1912. St. Clair Co., near Port Huron, C. K. Dodge, June, 1892. Gratiot Co., Alma, C. A. Davis, May, 1891. Midland Co., five miles north of Sanford, R. R. Dreisbach 4746. Antrim Co., Spencer Creek, C. Leavitt, June, 1891. Charlevoix Co., E. A. Bessey, Aug., 1912. Cheboygan Co., near Topinabee, J. H. Ehlers 6045. Delta Co., near Burnt Bluff, F. J. Hermann 6300. Mackinac Co., Goose Is., J. H. Ehlers 419.

Reported from: St. Joseph Co., Sturgis, F. P. Daniels, in 1903. Kalamazoo Co., C. R. and F. N. Hanes, in 1936. Bay Co., Linwood Beach, in 1926. Huron Co., Charity Is., C. K. Dodge, in 1911. Manistee Co., Manistee, F. P. Daniels, in 1903. Leelanau Co., Sister M. Marcelline Horton, in 1928. Grand Traverse Co., Sister M. Marcelline Horton, in 1929. Emmet Co., Gates and Ehlers, in 1924. Mackinac Co., Mackinac Is., C. K. Dodge, in 1913. Ontonagon Co., Porcupine Mts., H. T. Darlington. Keweenaw Co., near Black Creek, F. J. Hermann 615.

10. COPTIS Salisb.

Coptis groenlandica (Oeder) Fern., *Rhodora*, 31 : 142. 1929

C. trifolia of American authors, not Salisb.

Mossy woods, bogs and swamps; commoner northward.

Specimens examined. — Berrien Co., Paris, H. M. Bailey, May, 1892. Cass Co., Dowagiac, L. M. Umbach, Aug., 1904. Hillsdale Co., Hillsdale, D. A. Pelton, May, 1885. Washtenaw Co., Ann Arbor, W. Lewis, May, 1892. Ingham Co., Lansing, C. A. Davis, June, 1892. Oakland Co., Bloomfield Hills, C. Billington, May, 1916. Ottawa Co., Holland, C. H. Kauffman, Aug., 1910. Genesee Co., Flint, D. Clark 954. St. Clair Co., near Port Huron, C. K. Dodge, May, 1892. Gratiot Co., Alma, C. A. Davis, May, 1888. Midland Co., near Midland, R. R. Dreisbach 4693. Wexford Co., Harrietta, H. C. Skeels, May, 1895. Antrim Co., Elk Rapids, A. B. Lyons, in 1867. Cheboygan Co., Burt Lake, C. O. Erlanson 212. Schoolcraft Co., near Gulliver Lake, J. H. Ehlers 4327. Mackinac Co., Prentis Bay, J. H. Ehlers 1447. Chippewa Co., Sugar Is., F. J. Hermann 7039. Marquette Co., Marquette, A. Dachnowski, Aug., 1906. Gogebic Co. (?), Mamie Lake, H. T. Darlington, Aug., 1919. Houghton Co., near Laurium, F. J. Hermann 251. Keweenaw Co., Eagle Harbor, F. J. Hermann 7574.

Reported from: Kalamazoo Co., C. R. and F. N. Hanes, in 1936. Jackson Co., G. H. Hicks, in 1893. Iosco Co., Au Sable River, Sister M. Marcelline Horton, in 1939. Emmet Co., Gates and Ehlers, in 1924. Ontonagon Co., Porcupine Mts., H. T. Darlington.

11. DELPHINIUM L.

Delphinium Ajacis L.

Roadside. An escape from cultivation which is reported to persist.

Specimen examined. — St. Clair Co., Port Huron, C. K. Dodge, Sept., 1892.

Reported from: Van Buren Co., Keeler, H. S. Pepoon, in 1908. Kalamazoo Co., C. R. and F. N. Hanes, in 1936. Washtenaw Co., Ypsilanti, O. A. Farwell, in 1894.

12. ACTAEA L.

a. Pedicels slender, long, hollow; inflorescence an ovoid cluster; fruits with numerous seeds, 11–17
  b. Fruit red .... 1. *A. rubra*
  b. Fruit white .... 1a. *A. rubra* f. *neglecta*
a. Pedicels stout, solid; inflorescence elongate-oblong; fruits with not very numerous seeds, 9–14; fruit white .... 2. *A. pachypoda*

1. *Actaea rubra* (Ait.) Willd.

Swamps and rich woods; increasingly common northward.

Specimens examined. — Allegan Co., Swan Creek Experiment Station, F. W. Stuewer 224. Washtenaw Co., Lefurge Woods, B. A. Walpole, May, 1918. Wayne Co., Birmingham, J. M. Sutton 408. Ingham Co., East Lansing, H. C. Skeels, May, 1894. Oakland Co., Goodison, O. A. Farwell 7784. St. Clair Co., near Port Huron, C. K. Dodge, Aug., 1896. Gratiot Co., Alma, C. A. Davis, June, 1891. Roscommon Co., Higgins Lake, H. T. Darlington, July, 1916. Kent Co., Grand Rapids, S. R. Bailey, Aug., 1893. Iosco Co., along Cooke Dam Pond, J. H. Ehlers 4775. Emmet Co., Arnott Lake, C. O. Erlanson 413. Cheboygan Co., Burt Lake, C. O. Erlanson 246. Mackinac Co., Prentis Bay, C. O. Erlanson 667. Marquette Co., B. Barlow, May, 1901. Gogebic Co., near Watersmeet, H. T. Darlington, Aug., 1919. Ontonagon Co., Porcupine Mts., H. T. Darlington, Aug., 1923. Houghton Co., near Bear Lake, F. J. Hermann 432, 675. Keweenaw Co., Bête Gris, F. J. Hermann 335; Isle Royale, A. E. Foote, in 1868.

Reported from: Berrien Co., Warren Woods, C. Billington, in 1925. Kalamazoo Co., C. R. and F. N. Hanes, in 1936. Saginaw Co., Sister M. Marcelline Horton, in 1925. Grand Traverse Co., Sister M. Marcelline Horton, in 1928.

1a. *Actaea rubra* (Ait.) Willd. f. *neglecta* (Gillman) Robinson

A. eburnea Rydb.
A. alba (L.) Mill. according to Marie-Victorin in *Flore Laurentienne* (p. 232).

Specimens examined. — Kent Co., Grand Rapids, S. R. Bailey, Aug., 1893. Roscommon Co., island in Higgins Lake, C. Billington, Aug., 1919. Emmet Co., Cecil Bay, J. H. Ehlers 1659, 2167. Cheboygan Co., Douglas Lake, F. C. Gates, July, 1911. Mackinac Co., Bois Blanc Is., J. H. Ehlers 5148. Houghton Co., F. J. Hermann 779. Keweenaw Co., near Ojibway, F. J. Hermann 2181.

2. *Actaea pachypoda* Ell. (Marie-Victorin, *Flore Laurentienne*, p. 232. 1935)

A. alba of recent American authors; doubtfully *A. spicata* var. *alba* of L.

Rich woods.

Specimens examined. — Berrien Co., Warren Woods, C. Billington, July, 1919. Cass Co., Magician Lake, L. M. Umbach 961. Van Buren Co., South Haven, L. H. Pennington, June, 1910. Washtenaw Co., Cascade Glen, Ann Arbor, F. J. Hermann 6883. Wayne Co., Detroit, O. A. Farwell 7809. Ingham Co., Lansing, in 1864. Oakland Co., Walled Lake, O. A. Farwell 4491. Ottawa Co., Grand Haven, Lewis Foote, Aug., 1870. Kent Co., Grand Rapids, H. M. Bailey, Aug., 1891. Ionia Co., Hubbardston, C. F. Wheeler. St. Clair Co., near Port Huron, C. K. Dodge, June, 1892. Muskegon Co., Slocum, C. D. McLouth, Aug., 1899. Newaygo Co., Hess Lake, H. T. Darlington, Aug., 1916. Bay Co., Bay City, I. Tillapaugh 189. Arenac Co., Big Charity Is., C. K. Dodge, Sept., 1910. Charlevoix Co., E. A. Bessey, Aug., 1912. Cheboygan Co., Burt Lake, J. H. Ehlers 3341. Schoolcraft Co., dune region of Gulliver Lake, J. H. Ehlers 4169. Mackinac Co., dune region of Brevort Lake, J. H. Ehlers 4490. Marquette Co., B. Barlow, Aug., 1901. Ontonagon Co., Porcupine Mts., H. T. Darlington, Aug., 1923. Houghton Co., west of Calumet, F. J. Hermann 433. Keweenaw Co., O. A. Farwell, July, 1888.

Reported from: Kalamazoo Co., C. R. and F. N. Hanes, in 1936. Montcalm Co., Pierson Township, Sister M. Marcelline Horton. Saginaw Co., Sister M. Marcelline Horton, in 1923. Manistee Co., Manistee, F. P. Daniels, in 1903. Leelanau Co., Sister M. Marcelline Horton, in 1928. Emmet Co., Gates and Ehlers, in 1924. Gogebic Co., H. T. Darlington, in 1920.

13. HYDRASTIS Ellis

Hydrastis canadensis L.

Rich woods in the three southernmost tiers of counties; rare.

Specimens examined. — Hillsdale Co., near Hillsdale, D. A. Pelton, May, 1888. Washtenaw Co., Third Woods, Ann Arbor, F. J. Hermann 104. Ingham Co., Lansing, F. L. Sleeper, May, 1867. Oakland Co., Commerce, O. A. Farwell 7386. St. Clair Co., near Port Huron, C. K. Dodge, June, 1899.

Reported from: St. Joseph Co., Sturgis, F. P. Daniels, in 1903. Kalamazoo Co., C. R. and F. N. Hanes, in 1936.

EXCLUDED SPECIES

Ranunculus Cymbalaria Pursh

Oxygraphis Cymbalaria (Pursh) Prantl.
Halerpestes Cymbalaria (Pursh) Greene.

Reported from South Haven by Beal in *Michigan Flora.* He ascribes the report to L. H. Bailey, but no specimen could be found to confirm the record.

Ranunculus bulbosus L.

Specimens of this introduced species from Washtenaw and Ingham counties have been seen. Beal reports it from Bay, Chippewa, and Keweenaw counties, with the statement "a bad weed in meadows." No recent specimens are known, however, the only two collections which could be found having been made in 1863 and 1894. The plant is evidently not becoming established in the state.

R. bulbosus resembles *R. acris* in habit but may be distinguished from that species by its stalked terminal leaflets, the swollen, corm-like base of its stem, and its reflexed sepals.

Ranunculus acris var. *flore pleno* Hort.

O. A. Farwell reported this horticultural form as an escape around Ypsilanti in 1894.

A double-flowered race of *R. acris* was reported from Cheboygan Co. by Gates and Ehlers in 1931. It is presumably an escape, but is spreading.

Ranunculus trifoliatus Muhl.

No specimens of this plant could be found, but O. A. Farwell reports it for Stony Creek and La Salle in Washtenaw and Monroe counties. *R. trifoliatus* resembles *R. septentrionalis* and may be an ecological form of it. *R. trifoliatus* is a plant of dry land, early becoming glabrous and rarely stoloniferous.

Ranunculus lucidus Poir. ?

O. A. Farwell reported this species from Monroe Co. in 1921. Other reports or specimens were not found.

Ranunculus Macounii Britton

I am referring to this species a collection by H. S. Pepoon, from Van Buren County, June, 1906. Two others, Alger Co., Chatham, C. F. Wheeler, Aug., 1900, and Gogebic Co., Slate River, H. T. Darlington, Aug., 1919, appear to be nearest *R. Macounii*, and the localities are more compatible with its known range, but because these specimens are incomplete they cannot be placed with certainty.

Ranunculus lapponicus L.

Beal reports this species from "Thunder Bay, Lake Superior, Britton and Brown." This Thunder Bay is on the north shore of Lake Superior, in Ontario, and is not the Thunder Bay near Alpena, Michigan.

Thalictrum polygamum Muhl.

Reported from Gogebic Co. by Darlington and from Keweenaw Co. by Beal for Farwell, but no corroborating specimens could be located. The occurrence of the plant in Michigan is improbable since, as the species is now interpreted, its range does not extend west of the Alleghenies. Its nearest ally, *T. perelegans* Greene, occurs farther west and probably does extend north of Indiana.

T. polygamum may be distinguished from the common *T. dasycarpum* by its ovate, obtuse anthers, which are less than a millimeter in length. The anthers of *T. dasycarpum* are linear and mucronate.

Anemone riparia Fern.

No Michigan collections of this species were found. Beal ascribes reports for it from Wayne and Oakland counties to Farwell.

Anemone parviflora Michx.

In Beal's *Michigan Flora* reports for the state, without more definite locality, are credited to A. B. Lyons and Asa Gray. The report by Macoun from Pic River, Lake Superior, which is also cited by Beal, pertains to Ontario.

Anemone patens L. var. *Wolfgangiana* (Bess.) Koch.

No specimen could be located to substantiate Beal's report of this Anemone (as *Pulsatilla hirsutissima*) from Dickinson Co. The re-

port is ascribed to S. M. Tobey. Farwell reported it, as *Pulsatilla patens* var. *Wolfgangiana*, from Keweenaw Co.

Aquilegia vulgaris L.

The cultivated columbine occasionally escapes from gardens and has been reported from Keweenaw Co. by Farwell, from Washtenaw Co. by Walpole, and from Mackinac Is. by Dodge. There is no evidence to indicate that it has become established in Michigan.

Trollius laxus Salisb.

Beal credits a report of the globeflower from Genesee Co. to A. W. Chase, and the species is ascribed to Michigan in *Gray's New Manual*, Seventh Edition, and in Britton and Brown's *Illustrated Flora*, Second Edition, but no specimens from Michigan have been found.

Delphinium Consolida L.

A European species reported from Washtenaw Co. by Farwell in 1894, but no specimen could be found. Practically all American reports of this species prove to have been based upon specimens of *D. Ajacis*.

UNIVERSITY OF MICHIGAN

NEW AND UNUSUAL AGARICS FROM MICHIGAN. II *

ALEXANDER H. SMITH

THE six species of agarics reported in this paper are distributed in Collybia, Lactarius, Lepiota, Pleurotus, Marasmius, and Psilocybe. Two of these have not previously been described, two are new to the Michigan flora, and two hitherto poorly known have been critically studied. The specimens have been deposited in the University of Michigan Herbarium. All color names within quotation marks are taken from R. Ridgway, *Color Standards and Color Nomenclature*, Washington, D.C., 1912. A solution of five parts chloral hydrate, two parts water, and an excess of iodine was used to determine the iodine reaction of the spores.

List of Species

Collybia hymenocephala, sp. nov. — Pileus 2–3 cm. latus, convexus, glaber, olivaceobrunneus, hygrophanus, demum pallidus, atomatus; lamellae denticulatae, latae, pallidae demum cinereae; stipes 4–5 cm. longus, 2–3 mm. crassus, aequalis, solidus, cartilagineus, striatus, pallide cinereus; sporae 6–7 × 5–5.5 μ, ellipsoideae. Specimen typicum legit A. H. Smith n. 11050, prope Dexter, Mich., Sept. 23, 1938; in Herb. Univ. Mich. conservatum.

Pileus 2–3 cm. broad, convex or obtuse when young, the margin at first incurved, broadly convex to plane in age, glabrous, "olive-brown" to "buffy brown" when fresh, hygrophanous, fading to "tilleul buff" (whitish), or more olivaceous gray, atomate and glistening when faded, not striate; flesh concolorous with the surface in moist or faded condition, thin, very soft and fragile, odor not distinctive, taste slightly farinaceous; lamellae depressed-adnate but toothed, subdistant (18–20 reach the stipe), 2–3 tiers of short individuals, moderately broad (2.5–3 mm.),

* Papers from the Herbarium of the University of Michigan.

"tilleul buff" or becoming darker and grayish in age, edges slightly uneven; stipe 4–5 cm. long, 2–3 mm. thick, equal, solid, cartilaginous, fragile, longitudinally appressed-fibrillose-striate (not with superficial fibrils and not pruinose near the apex), color pallid to ashy brown (almost concolorous with the faded pileus); spores 6–7 × 5–5.5 μ, broadly ellipsoid, white in mass, dark blue in iodine, smooth; basidia four-spored, 26–28 × 7–8 μ; pleurocystidia and cheilocystidia not differentiated; gill trama homogeneous, pale sordid yellowish brown in iodine; pileus trama corticated by a palisade of inflated, pedicellate cells 25–36 × 20–25 μ, the remainder homogeneous.

Scattered on wet ground near the edge of a swampy area, Dexter, September 23, 1938 (no. 11050).

I have found this species but once. Its characters are so distinctive, however, that I have no hesitation in describing it. The lax flesh, the pale sordid olive-brown color of the pileus when moist, the atomate glistening appearance of faded specimens, the palisade of inflated cells over the pileus, and the strong bluish reaction of the spores in iodine are all outstanding. In stature it resembles *Collybia ludoviciana* Murr., which, however, is much more cartilaginous (dried material of both compared), and its spores are yellowish in iodine. *C. fissilis* Maire is also readily distinguished by the iodine reaction of the spores.

Lactarius psammicola, sp. nov. (Pl. I). — Pileus 5–10 cm. latus, subinfundibuliformis, glutinosus, valde strigosus demum subglaber, zonatus, aurantiacus vel pallide aurantiacoluteus; lac album demum in speciminibus fractis pallide vinaceum, intense acre; lamellae confertae, angustae, decurrentes, pallidae demum subochraceae; stipes 1–3 cm. longus, 1.5–2 cm. crassus, scrobiculatus, farctus demum cavus, pallidus; sporae 7–8 × 5–6.5 μ. Specimen typicum legit A. H. Smith n. 1710, prope Dexter, Mich., Aug. 5, 1935; in Herb. Univ. Mich. conservatum.

Pileus 5–10 cm. broad, the center deeply depressed, the margin inrolled, expanding and broadly vase-shaped in age, glutinous and slimy when fresh, surface covered by masses of agglutinated fibrils, margin coarsely fibrillose or strigose at first, merely appressed-fibrillose in age, conspicuously zonate when young, obscurely so in age, colors "ochraceous buff" to "ochraceous orange" and zoned by "light buff" bands, finally becoming

sordid yellowish brown; flesh thick, tapered evenly to the margin, sordid buff, exuding a white latex when cut or bruised; latex copious, staining the lamellae "pale grayish vinaceous" (pinkish lilac) or changing very slowly to that color when in contact with the air, extremely acrid; lamellae close, narrow, decurrent, "light buff" to nearly white at first, becoming darker and sordid ochraceous in age; stipe 1–3 cm. long, 1.5–2 cm. thick, whitish, at times scrobiculate-spotted, tapering abruptly at the base, interior stuffed to hollow and whitish or sordid gray; spores 7–8 $\times$ 5–6.5 μ, ellipsoid, coarsely reticulated.

Gregarious on sandy soil under scrub oak and aspen near Dexter, August 5, 1935 (no. 1710, type). Additional collections were found near Pinckney and Ann Arbor during the same season.

This is a curious species because of its colors and very acrid taste, combined with the slowly changing milk and coarse fibrils, which at first cover the pileus. It is similar in many respects to *Lactarius torminosus* Fr., but differs decidedly in color. The colors are very similar to those of *L. insulsus* Fr., but usually a little paler (yellowish orange). Specimens were sent to Miss G. S. Burlingham, who reported that she knew of no described species with these characters. She commented on the similarity of the spores of *L. psammicola* to those of *L. torminosus*, and expressed the opinion that the former would have to be distinguished by the changing milk and the fibrillose surface of the entire pileus. I have collected *L. torminosus* in the same locality with *L. psammicola*, and have found the fibrillose surface covering to vary greatly in both species. In each it is sometimes very dense and persistent over the entire cap. The darker colors and the changing milk of the latter are sufficient to distinguish it.

Lepiota lenticularis (Lasch) Gillet (Pl. II). — Pileus 6–15 cm. broad, very obtuse when young, becoming broadly umbonate at maturity or the margin elevated slightly and the umbo disappearing, glabrous and viscid when young, in age the cuticle sometimes separating into fibrils and then appearing obscurely virgate, margin often splitting radially, cuticle sometimes subrimose, the exposed flesh appearing whitish, cuticle evenly "vinaceous buff" and remaining so throughout development, in

age the disc often marked with roundish more or less watery spots, margin incurved and cottony-fibrillose when young; flesh white, thick (7–8 mm. near the stipe), unchanging, odor subfarinaceous when cut, taste almost mild or slightly fungoid; lamellae approximate to the stipe but free, very close (120–130 almost reach the stipe), many short individuals present, broad (1 cm. ±), pure white until late maturity, then dull grayish to olivaceous gray, especially along the edges; stipe 10–15 cm. long, 1–2.5 cm. thick, solid, base somewhat enlarged into an oval bulb which is rounded below, conspicuously longitudinally appressed-fibrillose-striate above and below the superior membranous annulus, neither scaly nor sheathed, flesh nearly "tilleul buff" (pallid), surface somewhat darker; annulus membranous, thin, sometimes evanescent, fibrillose above and below, dull pale vinaceous gray, paler than the pileus; spores $4–5 \times 3.5–4$ μ, white in mass, ellipsoid to subglobose, not amyloid, smooth; cheilocystidia and pleurocystidia not differentiated; pileus trama homogeneous beneath a thin gelatinous pellicle, as in *Lepiota solidipes* Pk.; see Smith (7).

Gregarious under elm and ash in a dry swamp, South Lyons, October 5, 1938 (no. 11105).

My specimens were collected in very dry weather, and the only traces of olive color appeared near the edges of the gills in old pilei. In Europe the species is generally described as having exuded drops of liquid on various parts, and these are said to become sordid olivaceous as they dry. Considering the circumstances under which my specimens were collected, the absence of such drops and the stains which result from them is not taxonomically significant.

In the Michigan collection the stipe was solid and not scaly. Lange (5) illustrates the species as having a scaly stipe, but Fries (3) has not shown this character in his illustration, although he described it (2) as "plus minus *squamulosus*, interdum fere glaber . . . ." He also described it as "solidus, sed admodum spongioso-mollis (nec durus, rigidus uti prioris)." The fibrillose coating over the stipes of my specimens could very easily become torn into squamules. Had these specimens possessed truly glabrous stipes with a smooth polished cuticle, the difference would be more important.

Lepiota Fischeri Kauff. is very close to this species, as Kauffman pointed out. It has, however, smaller spores, a differently colored pileus, and a peculiar odor when drying.

MARASMIUS POLYPHYLLUS Pk. — Pileus 2–4 cm. broad, convex when young, soon plane or with the margin recurved and wavy, color "vinaceous tawny" with a paler margin at first, in age with a "vinaceous tawny" eyespot on the disc, the remainder white or tinged pinkish vinaceous, margin becoming lacerated, surface glabrous (very finely silky under a lens), often irregularly cracked; flesh moderately thick on the disc (1 mm. ±), white, pliant, when crushed having an odor of spoiled garlic, taste similar but not exceptionally strong; lamellae very crowded, many short individuals present, many forking or anastomosing, free or attached by a tooth, narrow (1 mm.), edges even, white, unchanging; stipe 3–5 cm. long, 1–2 mm. thick, equal or narrowed below, hollow, pliant, evenly covered by a coarse white tomentum, with a faint tinge of pinkish brown showing through near the base, base surrounded by a mass of white mycelium; pileus trama homogeneous, no differentiated surface layer present; cheilocystidia and pleurocystidia none; basidia four-spored; spores narrowly ellipsoid, 6–7 × 3 μ, smooth, not amyloid; gill trama and pileus trama yellow in iodine.

In clusters of three to four individuals or singly on fallen leaves, near Dexter, September 23, 1939 (no. 11056). It has also been found in the vicinity of Milford (no. 10947).

Kauffman (4) pointed out that the relationships of this species are with *Marasmius prasiosmus*. In the characters of the gills and spores as well as in the pubescence which covers the stipe and in its stature, *M. polyphyllus* appears to me to be more closely related to *M. urens*. The taste, though persistent, is not so pronounced as in other species with similar odors and tastes. There appears to be no reason for considering Marasmii with a garlic or onion-like taste and odor as forming a phylogenetic series.

PLEUROTUS MASTRUCATUS (Fr.) Sacc. — Pileus 2–7 cm. broad, resupinate at first, becoming fan-shaped or spathulate, thick and fleshy, the upper half of the trama consisting of a gelatinous layer, the lower half white and floccose-filamentose, when young the surface covered by somewhat imbricate conic gelatinous

rigid spines, as expansion takes place the spines becoming separated from one another and remaining connected by raised lines giving the pileus a reticulate or netted appearance between projections, projections most numerous near the margin, white-villose or tomentose on or toward the base, margin long remaining inrolled, colors "dark Quaker drab" when young and fresh (with a distinct violet tinge), "light mouse-gray" or grayish white when very faded; lamellae white but becoming grayish, moderately broad (3–4 mm.), subdistant to close (5–8 tiers of short individuals), radiating from a point near the place of attachment to the substratum, edges cracking readily; stipe none; odor and taste slightly subnauseous; spores 7–8 × 4–5 μ, ellipsoid; pleurocystidia and cheilocystidia similar and abundant, 60–80 × 10–16 μ, originating in the subhymenium.

Imbricate on an old hickory log, near Dexter, October 18, 1939 (no. 14956). The collection was made by a group of mycological students. Kauffman included the species in his *Agaricaceae of Michigan* because it had been found in neighboring states. Apparently the 1939 record is the first one from Michigan.

PSILOCYBE ATROBRUNNEA (Lasch) Gillet (Pl. III). — Although Kauffman included this species in his *Agaricaceae of Michigan*, his description does not contain certain details which are essential for the recognition of the fungus. For the past nine years I have collected the fungus quite regularly in bogs in the vicinity of Ann Arbor, and have made a detailed study of it. In the light of Favre's recent description of *Psilocybe turficola* (1), and specimens which have been received from Seth Lundell of Upsala, Sweden, under the name *P. dichroa* Karst., it seems pertinent to publish at this time a detailed account of the American fungus. The microscopic characters of Kauffman's specimens have been studied from the two collections preserved in the University of Michigan Herbarium. Furthermore, during the season of 1929 Kauffman personally checked the writer's identification. The following description has been drawn from fresh material collected at Mud Lake Bog, Whitmore Lake.

Pileus 1.5–4 (5.5) cm. broad, conic-campanulate, mammillate or convex, becoming plane or with an obtuse umbo, margin inrolled at first and faintly white-fibrillose from the remains of

a rudimentary veil, soon glabrous over all, surface viscid or subviscid with a thin subseparable gelatinous pellicle, color "carob brown," "Rood's brown," "Mars brown," or "Prout's brown" (sordid to bright cinnamon-brown) at first, usually blackish in age when wet, margin sometimes faintly pellucid striate, hygrophanous, fading to "cinnamon-buff" or darker and with a more or less ochraceous disc; flesh thickish, pliant and fairly tough, dark brown and watery at first, fading to "cinnamon-buff," odor faint and hardly distinctive, taste farinaceous; lamellae close, broad, adnate, soon seceding, pallid "cinnamon-buff" when young, dark purplish brown in age, edges white-fimbriate; stipe 8–18 cm. long, 2.5–6 mm. thick, equal and flexuous, stuffed by a white pith but soon hollow, cartilaginous and tough, at first more or less evenly covered with a coating of appressed-white fibrils up to the faint zone left by the rudimentary veil, apex pruinose, veil fibrillose and very distinct in button stages, surface dull grayish brown beneath the fibrils, in age becoming bister from the base upward; spores 9–11 (12.5) $\times$ 5–7 μ, with an apical hyaline germ pore, dark purplish brown in mass; basidia four-spored, occasionally two-spored; pleurocystidia scattered to abundant, 36–44 $\times$ 5–10 μ, ventricose near the base, with a slender tapered neck; cheilocystidia similar and very abundant, forming a sterile band on the edge of the gill; pileus trama homogeneous beneath a thin gelatinous pellicle.

Certain irregularities have been noticed among collections from the same swamp obtained at different times over a period of years. In no. 14944 the spores measure 8–10 $\times$ 5–6 μ. In collections previous to that one the spores measure 9–11 (13) μ long. In one of Kauffman's collections two-spored basidia are rather frequent, and the spores in my mounts from it measured 10–12 μ long, with some 13–16 μ. In addition to the variability of the spore size, pleurocystidia are sometimes very rare and difficult to locate because they are inconspicuous and scattered. Lundell, in a letter to me, commented upon this last character, so that it is apparent that a similar situation prevails in northern Europe.

Lange (6) has classified under the name *Psilocybe dichroa* Karst. a species which is probably identical with *P. squalidella*

Pk. Favre (1) believes that his *P. turficola* is identical with Kauffman's *P. atrobrunnea*. I am of the same opinion. European authors have apparently reserved the name *P. atrobrunnea* for a species with a radish-like odor. In all other respects, however, the descriptions of *P. atrobrunnea* agree remarkably well with those of American material. I question the advisability of placing much emphasis on the radish-like odor in this instance. I have found specimens of *Mycena glaericulata* with such an odor, but the character is not at all constant in that species. In *M. pura*, however, the opposite is true, as everyone knows. Many observations are desirable to establish an odor of this type as a reliable specific character. The size of the pileus as described for the fungus in Europe by no means excludes the American material. The outstanding macroscopic character of the species, and the one emphasized by the early descriptions, is the long, equal, flexuous, fibrillose stipe. In comparison with most of the early descriptions that of *P. atrobrunnea* covers the plant in question remarkably well. Since the name *P. atrobrunnea* is the oldest, it should be used in preference to any of the later ones.

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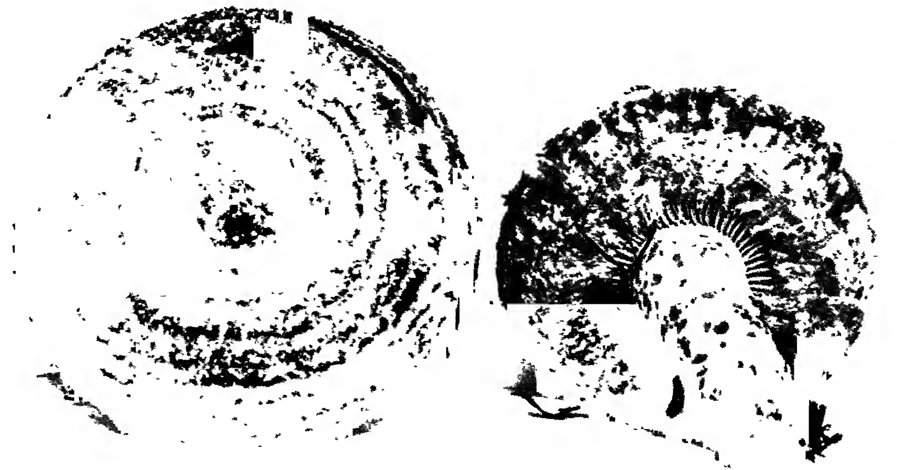

Lactarius psammicola, sp. nov. × 1

Lepiota lenticularis (Lasch) Gillet. × 1

Psilocybe atrobrunnea (Lasch) Gillet. × 1

NOTES ON THE MARINE ALGAE OF TEXAS

WM. RANDOLPH TAYLOR

FIVE years ago in an article in the *Papers of the Michigan Academy of Science, Arts, and Letters* (Taylor, 1936) I included all the records of marine algae from Texas of which I was then aware. In the meantime three considerable collections of Texan marine algae and several smaller collections have come into my hands. Since they suffice to more than double the existing record of the marine flora it seems appropriate to list their contents and to direct attention to some of their more interesting features.

The earliest collection received consists of the marine algae preserved by Arthur Schott and loaned by the Field Museum of Natural History through the kindness of Dr. C. C. Gregg, the director, and of Dr. Francis Drouet, the curator of cryptogams. The collection contains about forty-five sheets of Texan algae, of which two thirds contribute to this account; the remaining algae either are unsuitable for study or, in a few instances, must be held until they are better understood. Schott, though chiefly concerned with flowering plants, was an omnivorous collector, and considerable numbers of marine algae which he assembled from other parts of North and South America are available for later study. It appears that during the period 1853–55 he was assistant to Major Emory in the Mexican Boundary Survey and besides performing his engineering duties collected plants and prepared some of the illustrations for the report of the survey (Emory, 1857). His Texan algal specimens are often small and poor, but they are very interesting and are exceeded in variety only by the most recent collections, made over seventy-five years later. They come chiefly from a place designated "Indianola" and shown in the map attached to the survey report as on the southwest shore of Matagorda Bay; the other station commonly mentioned is "Boca del Rio Bravo del Norte" — near the mouth of the Rio Grande, as it is now called. A few specimens are noted simply as from the "Gulf of Mexico," but they were collected during 1853, when Schott was in

Texas, and not in 1864–65, when he was in Yucatan, or later in 1865 when he was in Cuba, so that their Texan origin seems certain. The Schott algae were identified to some extent by their collector, but his names are commonly incorrect. With the specimens as mounted by the Field Museum are manuscript determinations made by W. G. Farlow. I have, however, confirmed or redetermined all that I report here.

The next collection in time of inception, a much larger one, is that assembled by Mr. Clyde T. Reed during the years 1928–39. It came from the southern part of the coast and adds considerably to the known flora. I am greatly indebted to Mr. Reed for the opportunity of studying this material.

The last of the larger collections is that made by Miss Beulah Smith; it was submitted to me for study by the kind intervention of Professor Frederick McAllister, of the University of Texas. This collection is particularly useful because it includes a number of northern stations and derives from more sources (about fifteen) than the others, which have a more restricted range.

In addition, I am indebted to Mr. Robert Runyeon, of Brownsville, for several specimens submitted and to the Field Museum and others for occasional sheets.

The material loaned by the Field Museum has naturally been returned there for deposit. Since that submitted by Miss Smith and Mr. Reed exists in duplicate, a part has been retained by the collectors and a part deposited in the Herbarium of the University of Michigan.

In listing these plants I have included the names reported in my earlier note (Taylor, 1936), that the account might be more complete, but it should be realized that a number of these were transcribed from the report ("O. S.," 1931) of M. A. Howe's determinations. So far as the new records are concerned, I am responsible for all the determinations.

As usual in early American algal collections, the stations given are often vague (though not ordinarily so vague as Schott's "Gulf of Mexico"), and sometimes they are so local as to defy discovery on general maps. In this paper the records are referred to the bay or island from which they came, or to the nearest large settlement. The approximate latitudes of the places mentioned are as follows: Texas City, 29° 20′; Galveston, 29° 15′; Palacios, 28° 45′; Lavaca

Bay, 28° 40′; Matagorda Bay, 28° 35′; Indianola, 28° 30′; Goose Island, 28° 10′; Copano Bay, Port Bay, and Aransas Bay, 28° 05′; Rockport, 28° 00′; Ransom Island, Port Aransas, and Aransas Pass, 27° 55′; Corpus Christi, Corpus Christi Bay, and Mustang Island, 27° 45′; Baffin Bay, 27° 15′; Padre Island, 27° 00′; Point Isabel and Brazos Santiago, 26° 10′; mouth of the Rio Grande, 25° 55′.

It is still too early to consider that the full character of the Texan marine flora is shown by the records, and additional species will, obviously, be brought to light. The impression strengthens, however, that the flora is a limited one, as determined by the sandy or muddy character of the shore line. These recent collections very markedly increase the representation of forms with tropical affinities. In the Chlorophyceae we find added *Acetabularia crenulata* and *Batophora Oerstedi;* in the Phaeophyceae, *Padina Vickersiae;* and in the Rhodophyceae, *Corallina cubensis*, *Jania capillacea*, *Chondria atropurpurea*, *Digenia simplex*, and others; on the east coast these plants are not known so far north as the Virginia capes. Outside of two or three species concerning the distribution of which little has been ascertained, all those reported from Texas are well known also from other stations much farther south. This seems to indicate that there is no marked North Temperate element in the flora and that it is composed of latitudinally wide-ranging species or of species only ranging south into the tropics. The dominant plants, such as the Enteromorphae, Ulvae, Gelidia, and Gracilariae, are clearly characteristic of relatively protected stations and known to be adaptable to reduced salinity. There are no species which are essentially reef plants, though *Laurencia papillosa* is certainly commonest on a reef or other rocky substrate.

List of Species

CHLOROPHYCEAE

ULVACEAE

Enteromorpha flexuosa J. Agardh. — Taylor 1928, p. 55, pl. 7, fig. 2. Rockport, Jan., 1936, *Reed;* Port Aransas, June, 1935, *Reed;* Corpus Christi, March, 1936, July, 1938, Feb., 1939, *Reed;* mouth of the Rio Grande, *Schott* no. 18 *p. p.*

Enteromorpha lingulata J. Agardh. — Taylor 1936, p. 201. Indianola, Jan. and Feb., 1853, *Schott* nos. 9, 9a, 17a, 17b; Port Aransas, June, 1935, July, 1938, *Reed;* Corpus Christi Bay, May and June, 1937, *Smith;* Corpus Christi, July, 1938, *Reed;* Baffin Bay, Jan., 1936, *Reed;* Brazos Santiago, Sept., 1938, *Runyeon;* mouth of the Rio Grande, Oct. (and perhaps in other months), 1853, *Schott* nos. 10, 18 *p. p.*, 192, 197; same, April, 1939, *Runyeon.*

Enteromorpha plumosa Kützing. — Harvey 1871, pl. 263, as *E. Hopkirkii.* Lavaca Bay, June, 1937, *Smith;* Corpus Christi Bay, March, 1936, and June, 1937, *Smith;* Mustang Island, June, 1937, *Smith.*

Enteromorpha prolifera (Müller) J. Agardh. — Taylor 1928, p. 56, pl. 3, fig. 19; 1937, p. 65, pl. 3, fig. 2. Corpus Christi Bay, March and April, 1936, *Smith;* Corpus Christi, March, 1936, *Reed.*

Ulva fasciata Delile. — Taylor 1936, p. 202. Port Aransas, May, 1933, and July, 1935, *Reed;* Brazos Santiago, Sept., 1938, *Runyeon.*

Ulva Lactuca L. — Taylor 1928, p. 57, pl. 3, figs. 20–21, pl. 7, fig. 7; 1936, p. 201; 1937, p. 75, pl. 4, fig. 6. Texas City, July, 1937, *Smith;* Galveston, 1878, Hb. F. M. N. H. nos. 797077, 797078; Palacios, Aug., 1937, *Smith;* Lavaca Bay, June, 1937, *Smith;* Matagorda Bay, June, 1937, *Smith;* Indianola, Feb., 1853, *Schott* no. 8 and also 1855, *Schott,* no number; Copano Bay, June and Aug., 1937, *Smith;* Rockport, March, 1932, *Reed;* Corpus Christi, Feb., 1934, and March, 1936, *Reed;* Corpus Christi Bay, Aug., 1937, *Smith.*

A good deal of this material tended toward var. *latissimum* (Linnaeus) De Candolle, of which Reed's no. 16 from Corpus Christi in 1934 is quite typical.

CLADOPHORACEAE

Chaetomorpha brachygona Harvey. — Taylor 1928, p. 60, pl. 4, fig. 12. Rockport, Aug., 1937, *Smith;* Port Aransas, March, 1937, *Sanders;* Corpus Christi Bay, Aug., 1937, *Smith;* Baffin Bay, Jan., 1936, *Reed.*

Chaetomorpha clavata (C. Agardh) Kützing. — Børgesen 1913–20, II, p. 16. Brazos Santiago, Sept., 1938, *Runyeon.*

Chaetomorpha geniculata Montagne? — Fulton Bay, Aug., 1937, *Smith.*

Cladophora fascicularis (Mertens) Kützing. — Taylor 1928, p. 62; 1936, pp. 201, 202. Port Aransas, May, 1928 and 1932, and May, June, and July, 1935, *Reed;* Corpus Christi, March, 1936, and July, 1938, *Reed.*

Cladophora glaucescens (Griffiths ex Harvey) Kützing. — Harvey 1871, pl. 196; Taylor 1937, p. 86. Corpus Christi, July, 1938, *Reed.*

Cladophora variegata (C. Agardh) Zanardini. — "O. S." 1931, p. 26.

DASYCLADACEAE

Acetabularia crenulata Lamarck. — Taylor 1928, p. 67, pl. 5, figs. 11, 22–24. Copano Bay, Aug., 1937, *Smith;* Aransas Pass, June, 1935, *Reed;* Ransom Island, Aug., 1937, *Smith.*

Batophora Oerstedi J. Agardh, var. occidentalis (Harvey) Howe. — Taylor 1928, p. 68, pl. 5, figs. 1–2, 15–16. Port Bay, June and Aug., 1937, *Smith.*

PHAEOPHYCEAE

ECTOCARPACEAE

Ectocarpus confervoides (Roth) Le Jolis. — Taylor 1936, p. 202; 1937, p. 109, pl. 8, figs. 1–3. Corpus Christi, Feb., 1939, *Reed.*

Ectocarpus Duchassaignianus Grunow. — Taylor 1928, p. 107, pl. 14, fig. 3; 1936, p. 202.

Ectocarpus Mitchellae Harvey. — Harvey 1852–58, I, p. 142, pl. 12, fig. G; "O. S." 1931, p. 26.

Ectocarpus Rallsiae Vickers. — Vickers 1908, p. 44, pl. 32; "O. S." 1931, p. 26.

Ectocarpus siliculosus (Dillwyn) C. Agardh. — Taylor 1936, p. 201; 1937, p. 108, pl. 8, figs. 4–5. Corpus Christi, March, 1936, *Reed.*

DICTYOTACEAE

Padina Vickersiae Hoyt. — Taylor 1928, p. 123, pl. 17, fig. 9 Port Aransas, May, 1932, and June, 1935, *Reed.*

FUCACEAE

Sargassum Filipendula C. Agardh. — Taylor 1928, p. 127, pl. 18, fig. 5, pl. 19, fig. 17; 1937, p. 210, pl. 27, figs. 4–6. Mouth of the Rio Grande, *Schott* no. 34.

In these specimens the leaves are very narrow and forked; although serrate in the wider examples they are nearly entire in those which are narrowest; the stem is almost smooth. Both *S. cymosum* and *S. Filipendula* may develop forked leaves, especially on the basal shoots. The stem in *S. cymosum*, however, is commonly minutely muriculate, and the leaves, particularly the broad ones, entire, so that the plant no. 34 is hardly a form of *S. cymosum*. Var. *Montagnei* of *S. Filipendula* is suggested on the old labels, but it is defined as having long-apiculate bladders, which are lacking here; the receptacles of the present plant are, further, rather too compactly branched for that variety. It seems best left as a variant of the polymorphic *S. Filipendula*.

Sargassum fluitans Børgesen. — Taylor 1928, p. 127, pl. 18, fig. 9, pl. 19, fig. 5; 1936, p. 201. Mustang Island, July, 1937, *Smith;* Padre Island, June, 1935, *Reed;* mouth of the Rio Grande, Nov.—Dec., 1853, *Schott* no. 189, *p. p.;* same, April, 1939, *Runyeon.*

Sargassum natans (Linnaeus) Meyen. — Taylor 1928, p. 128, pl. 18, figs. 2–4, pl. 19, fig. 13; 1936, p. 202; 1937, p. 212. Near Point Isabel, 1930, *O'Malley*, Hb. F. M. N. H. no. 975641; mouth of the Rio Grande, Nov.—Dec., 1853, *Schott* no. 189, *p. p.*

Sargassum pteropleuron Grunow. — Taylor 1928, p. 130, pl. 18, fig. 6, pl. 19, fig. 13. Mustang Island, June, 1937, *Smith.*

RHODOPHYCEAE

BANGIACEAE

Bangia fuscopurpurea (Dillwyn) Lyngbye. — "O. S." 1931, p. 26; Taylor 1937, p. 218, pl. 28, figs. 10–12.

Goniotrichum Alsidii (Zanardini) Howe. — Taylor 1937, p. 215, pl. 28, figs. 1–4. On Laurencia, Corpus Christi, Feb., 1939, *Reed.*

CHANTRANSIACEAE

ACROCHAETIUM CRASSIPES Børgesen. — Børgesen 1913–20, II, p. 20. On Polysiphonia, Corpus Christi, Feb., 1939, *Reed.*

ACROCHAETIUM VIRGATULUM (Harvey) Bornet. — Taylor 1937, p. 230, pl. 31, figs. 4–7, a variety. Aransas Pass, June, 1934, *Reed.*

GELIDIACEAE

GELIDIUM CORNEUM (Hudson) Lamouroux. — Greville 1830, p. 139, pl. 15, *p. p.;* Taylor 1928, p. 142, pl. 28, fig. 2; 1936, p. 201. Port Aransas, May, 1932, and June, 1934, *Reed;* same, March, 1937, *Sanders.*

Much of the Texas material of Gelidium, although probably ascribable to this species, is so narrow as hardly to appear flattened at all, and is very difficult to distinguish from some of the local forms called *G. crinale.* Because of this fact several specimens from other stations have not been listed.

GELIDIUM CRINALE (Turner) Lamouroux. — Taylor 1936, p. 202; 1937, p. 246, pl. 35, figs. 1–3, pl. 40, fig. 3, pl. 41, fig. 5. Galveston, June, 1937, *Smith;* Goose Island, Oct., 1937, *Smith;* Port Bay, Oct., 1937, *Smith;* Copano Bay, June, July, and Aug., 1937, *Smith;* Rockport, Jan., 1936, *Reed;* same, Sept., 1937, *Smith;* Port Aransas, May, 1932, and June, 1935, *Reed;* Aransas Bay, June, July, and Aug., 1937, *Smith;* Corpus Christi, June and Aug., 1936, 1937, *Smith;* same, July, 1938, and Feb., 1939, *Reed.*

GELIDIUM PUSILLUM (Stackhouse) Le Jolis. — Taylor 1928, p. 142, pl. 20, fig. 8, pl. 22, fig. 9, pl. 23, fig. 3; "O. S." 1931, p. 26.

CORALLINACEAE

CORALLINA CUBENSIS (Montagne) Kützing emend. Børgesen. — Børgesen 1913–20, II, p. 187; Taylor 1928, p. 205, pl. 29, fig. 12. Port Aransas, June, 1915, *Reed.*

JANIA CAPILLACEA Harvey. — Taylor 1928, p. 206, pl. 29, figs. 2, 10. Ransom Island, Aug., 1937, *Smith.*

SOLIERIACEAE

AGARDHIELLA TENERA (J. Agardh) Schmitz. — Taylor 1928, p. 147, pl. 13, fig. 1; 1936, p. 202; 1937, p. 286, pl. 38, fig. 4, pl. 40,

fig. 7, pl. 41, fig. 2, pl. 59, fig. 9. "Gulf of Mexico," 1853, *Schott* no. 198; Galveston Bay, April, 1939, *Burt;* Indianola, 1855, *Schott*, no number, *p. p.;* mouth of the Rio Grande, Nov., 1853, *Schott* no. 190.

EUCHEUMA ACANTHOCLADUM (Harvey) J. Agardh. — Taylor 1928, p. 148, pl. 31, fig. 1. "Gulf of Mexico," 1853, *Schott* no. 178, *p. p.*

HYPNEACEAE

HYPNEA CERVICORNIS J. Agardh. — Taylor 1928, p. 156, pl. 22, fig. 11; 1936, p. 201. Corpus Christi Bay, Aug., 1937, *Smith.*

HYPNEA MUSCIFORMIS (Wulfen) Lamouroux. — Taylor 1928, p. 156, pl. 22, fig. 10, pl. 23, fig. 12; 1936, p. 202; 1937, p. 291, pl. 37, fig. 2. Port Aransas, June, 1933, and May, 1935, *Reed;* Aransas Pass, June, 1935, *Reed;* Aransas Bay, June, 1937, *Smith;* Corpus Christi Bay, Aug., 1937, *Smith;* Brazos Santiago, Sept., 1938, *Runyeon.*

GRACILARIACEAE

GRACILARIA BLODGETTII Harvey. — Taylor 1928, p. 151, pl. 23, fig. 9, pl. 33, fig. 6; "O. S." 1931, p. 26.

GRACILARIA COMPRESSA (C. Agardh) Greville. — Harvey 1852–58, III, p. 108. "Gulf of Mexico," 1853, *Schott* no. 181.

GRACILARIA CONFERVOIDES (Linnaeus) Greville. — Taylor 1928, p. 152, pl. 23, fig. 10; 1937, p. 293, pl. 38, fig. 1. Galveston, Feb., 1854, *Schott*, no number; Indianola, Jan. and Feb., 1853, *Schott*, no number; Goose Island, July, 1935, *Reed;* Matagorda Bay, *Bailey*, Hb. F. M. N. H. no. 945315; same, June, 1937, *Smith;* Copano Bay, Sept., 1937, *Smith;* Rockport, June, 1935, *Reed;* Corpus Christi, March, 1930, *Benke* no. 5347; same, June, 1937, *Smith;* "Gulf of Mexico," 1853, *Schott* no. 187, *p. p.*

GRACILARIA CONFERVOIDES var. LONGISSIMUS Harvey. — Harvey 1852–58, III, p. 108. Corpus Christi, July, 1938, *Reed.*

GRACILARIA FOLIIFERA (Forsskål) Børgesen. — Taylor 1928, p. 155; 1936, p. 201, as *G. lacinulata;* 1937, p. 293, pl. 38, figs. 2, 3, pl. 41, fig. 1, pl. 59, fig. 7. Goose Island, July, 1935, *Reed;* Aransas Pass, June, 1935, *Reed;* Corpus Christi, July, 1938, *Reed.*

GRACILARIA FOLIIFERA var. ANGUSTISSIMA (Harvey) Taylor. — Taylor 1937, p. 294. Rockport, May, 1934, *Reed;* same, June

and Aug., 1937, *Smith;* Corpus Christi, March, 1936, *Reed;* Corpus Christi Bay, Aug., 1937, *Smith.*

GIGARTINACEAE

GIGARTINA ELEGANS Greville. — Brazos Santiago, Sept., 1938, *Runyeon.*

CERAMIACEAE

CENTROCERAS CLAVULATUM (C. Agardh) Montagne. — Taylor 1928, p. 189, pl. 28, figs. 6–7; 1936, pp. 201, 203. Indianola, Feb., 1854, *Schott,* no number, *p. p.*, and no. 25; Port Aransas, May and June, 1933, *Reed.*

CERAMIUM BYSSOIDEUM Harvey. — Taylor 1928, p. 190, pl. 27, figs. 20–21. Port Aransas, March, 1937, *Sanders;* Aransas Pass, June, 1934, *Reed;* Corpus Christi, Feb., 1939, *Reed.*

CERAMIUM STRICTUM (Kützing) Greville & Harvey. — Taylor 1937, p. 334, pl. 47, fig. 6, pl. 48, figs. 5–6, pl. 51, fig. 5. Indianola, Jan. and Feb., 1853, *Schott,* no number and nos. 34, 35.

CERAMIUM SUBTILE J. Agardh. — Taylor 1928, p. 192, pl. 27, figs. 17–19. Corpus Christi, July, 1938, *Reed.*

DASYACEAE

DASYA PEDICELLATA (C. Agardh) C. Agardh. — Taylor 1928, p. 173, pl. 35, fig. 7; 1937, p. 355, pl. 54, figs. 1–4. Indianola, Jan., 1853, *Schott* no. 6.

RHODOMELACEAE

BOSTRYCHIA MORITZIANA (Sonder) J. Agardh. — Taylor 1928, p. 166; 1936, p. 202; both as *Amphibia Moritziana,* syn.

BRYOCLADIA CUSPIDATA (J. Agardh) De Toni. — Taylor 1928, p. 168; 1936, p. 203. Port Aransas, May, 1932, *Reed;* Brazos Santiago, Sept., 1938, *Runyeon.*

CHONDRIA ATROPURPUREA Harvey. — Taylor 1928, p. 170. Corpus Christi, July, 1938, *Reed.*

DIGENIA SIMPLEX (Wulfen) C. Agardh. — Taylor 1928, p. 175, pl. 24, fig. 20, pl. 33, fig. 7. Indianola, Feb., 1853, *Schott,* no number; Rockport, Sept., 1937, *Smith;* Aransas Bay, May, 1936, June and Aug., 1937, *Smith;* Aransas Pass, June, 1935, *Reed;* Ransom Island, June, 1937, *Smith.*

LAURENCIA GEMMIFERA Harvey. — Harvey 1852–58, III, p. 73, pl. 18b. Aransas Pass, June, 1935, *Reed;* same, May, 1936, *Smith;* Ransom Island, June, Aug., and Oct., 1937, *Smith.*

LAURENCIA PAPILLOSA (Forsskål) Greville. — Taylor 1928, p. 180, pl. 35, fig. 4. Rockport, June, 1937, *Smith;* Aransas Pass, June, 1935, *Reed.*

LAURENCIA POITEI (Lamouroux) Howe. — Taylor 1928, p. 181, pl. 34, figs. 4, 10. Corpus Christi, May, 1937, *Smith;* mouth of the Rio Grande, Nov., 1853, *Schott* no. 191.

LOPHOSIPHONIA SUBADUNCA (Kützing) Falkenberg. — Howe 1920, p. 574. Growing on Digenia, Aransas Pass, June, 1935, *Reed.*

POLYSIPHONIA BINNEYI Harvey. — Taylor 1928, p. 183. Port Aransas, March, *Sanders.*

POLYSIPHONIA FERULACEA Suhr. — Taylor 1928, p. 183, pl. 24, figs. 16–18, pl. 25, fig. 15, pl. 26, figs. 11, 15. Indianola, 1855, *Schott,* no number; Port Aransas, March, 1937, *Sanders.*

WRIGHTIELLA TUMANOWICZII (Gatty) Schmitz. — Taylor 1928, p. 188, pl. 23, fig. 19; 1936, p. 203.

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FLORA OF HACIENDA VISTA HERMOSA, NUEVO LEÓN

A MESOPHYTIC NONALKALINE HABITAT IN THE EASTERN SIERRA MADRE OF MEXICO *

STEPHEN S. WHITE

THIS paper is based on collections made in June, 1939, by Mr. L. H. Harvey and the writer at Hacienda Vista Hermosa, Nuevo León, 25 miles south of Monterrey, Mexico. Since only a limited time could be spent here, collecting was restricted to the oak zone, at an elevation of about 2,400 feet, well above the dry lowlands. An important feature of this place, and the one which seems to account for the luxuriance of the vegetation, is a permanent spring-fed stream, which at one spot plunges over a 100-foot precipice to form the well-known Horse-Tail Falls. The falls themselves are of botanical interest because of the thick deposits of travertine on the face and at the base of the precipice, formed by the action of blue-green algae.

The stream supports a narrow fringe of vegetation of decidedly northern aspect, which presents a striking contrast to the drier oak forests more typical of the region. The dominant species here are *Juglans mollis*, *Carya myristicaeformis*, and *Ulmus divaricata*. The elm is of interest because it was first described by Mueller from Diente Canyon, about twelve miles south of Monterrey.[1]

In some places these trees shade out practically all herbaceous vegetation except ferns. The species found were *Adiantum Capillus-Veneris*, *Anemia mexicana*, *Dryopteris concinna*, *D. Féei*, *Llavea cordifolia*, *Pteris cretica*, and *Tectaria heracleifolia*.

Growing in the stream itself, or in open places along its banks, were two interesting aroids, *Xanthosoma robustum* and *Arisaema*

* Papers from the Department of Botany and Botanical Gardens of the University of Michigan, No. 720.

[1] Mueller, C. H., "New and Noteworthy Trees in Texas and Mexico," *Bull. Torr. Bot. Club*, 63: 147–155. 1936.

Dracontium. Other plants to be found in this walnut–hickory–elm association are *Salvia mexicana*, *Bassovia mexicana*, *Nama biflorum*, *Stellaria ovata*, *Anagallis arvensis*, *Spermacoce tenuior*, *Chiococca pachyphylla*, *Staphylea Pringlei*, *Phytolacca decandra*, *Scutellaria Seleriana*, *Cardamine auriculata*, *Linum cruciatum*, *Heimia salicifolia*, and *Sambucus mexicana*. A new species of Tragia was also discovered.

The vegetation of the oak forest proper closely resembled that of the corresponding zone of La Silla, which is described in the next paper, also by the writer. The collections made in the oak forest are included in the appended list.

The writer is indebted to Dr. I. M. Johnston for the determination of most of the specimens.

List of Species

Collection numbers are indicated in parentheses; those of L. H. Harvey are preceded by the letter H.

POLYPODIACEAE

Adiantum Capillus-Veneris L. (H–1036)
Dryopteris concinna (H. & B.) Kuntze (H–1060)
Dryopteris Féei C. Chr. (H–1084)
Llavea cordifolia Lag. (H–1033a)
Pteris cretica L. (H–1080)
Tectaria heracleifolia (Willd.) Underw. (H–1037)

SCHIZEACEAE

Anemia mexicana Kl. (H–1075)

SELAGINELLACEAE

Selaginella pilifera A. Br. (H–1033)

GRAMINEAE

Agrostis verticillata Vill. (H–1032, H–1034)
Andropogon saccharoides Swartz (H–1045, H–1066, H–1078)
Aristida spp. (H–1069, H–1076)
Bouteloua curtipendula (Michx.) Torr. (H–1071, H–1079)
Bouteloua filiformis (Fourn.) Griffiths (H–1077)
Bouteloua trifida Thurb. (H–1035)
Bromus texensis (Shear) Hitchc. (H–1040)
Cenchrus pauciflorus Benth. (H–1073)
Digitaria sanguinalis (L.) Scop. (H–1059, H–1067)
Eragrostis sp. (H–1064)
Hilaria mutica (Buckl.) Benth. (H–1034a)
Panicum fasciculatum Swartz (H–1046)
Panicum transiens Swallen (H–1058)

Paspalum conjugatum Bergius (H–1063)
Paspalum Langei Nash (H–1031, H–1039)
Paspalum lividum Trin. (H–1041)
Paspalum notatum Flügge (H–1047)
Paspalum unispicatum (Scribn. & Merr.) Nash (H–1074)
Piptochaetium fimbriatum (HBK.) Hitchc. (H–1038)
Setaria geniculata (Lam.) Beauv. (H–1070)
Sphenopholis obtusata (Michx.) Scribn. (H–1035a, H–1083)
Sporobolus Poiretii (R. & S.) Hitchc. (H–1043, H–1068)
Stipa mucronata HBK. (H–1042)
Trichachne californica (Benth.) Chase (H–1044)
Trichachne insularis (L.) Nees (H–1072)
Triodia texana S. Wats. (H–1048, H–1065)

ARACEAE

Arisaema Dracontium (L.) Schott (1512)
Xanthosoma robustum Schott (1639)

BROMELIACEAE

Tillandsia usneoides L. (1560)

FAGACEAE

Quercus Canbyi Trelease (1545, 1601)
Quercus polymorpha C. & S. (1600, 1609)

JUGLANDACEAE

Carya myristicaeformis (Michx.) Nutt. (1629)
Juglans mollis Engelm. (1633)

URTICACEAE

Parietaria debilis Forst. (1567)
Pilea microphylla (Sw.) Liebm. (1548)

ULMACEAE

Ulmus divaricata C. H. Muell. (1637)

AMARANTHACEAE

Amaranthus hybridus L. (1592)

PHYTOLACCACEAE

Phytolacca decandra L. (1511)
Rivina humilis L. (1558)

CARYOPHYLLACEAE

Stellaria ovata Willd. (1517)

RANUNCULACEAE

Clematis Drummondii T. & G. (1570)

PAPAVERACEAE

Argemone mexicana L. (1642)

CRUCIFERAE

Cardamine auriculata Wats. (1521)
Lepidium virginicum L. (1619)
Lepidium virginicum var. *pubescens* (Greene) C. L. Hitchc. (1641)

LEGUMINOSAE

Cercis canadensis L. (1538)
Galactia striata (Jacq.) Urban (1627)
Indigofera brevipes (Wats.) Rydb. (1585)
Medicago lupulina L. (1541)
Mimosa malacophylla Gray (1607)

LINACEAE

Linum cruciatum Planch. (1524)

RUTACEAE

Decatropis bicolor (Zucc.) Radlk. (1603)

MELIACEAE

Melia Azedarach L. (1565)

EUPHORBIACEAE

Acalypha phleoides Cav. (1559)
Croton sp. (1553)
Euphorbia spp. (1547, 1556)
Tragia sp., sp. nov. (1535)

ANACARDIACEAE

Rhus Toxicodendron L. (1543)

SAPINDACEAE

Sapindus Saponaria L. (1605)
Ungnadia speciosa Endl. (1604)

ACERACEAE

Acer Negundo L. (1638)

STAPHYLEACEAE

Staphylea Pringlei Wats. (1510)

RHAMNACEAE

Colubrina Greggii Wats. (1549)

VITACEAE

Vitis Berlandieri Planch. (1614)

MALVACEAE

Malvastrum coromandellianum (L.) Garcke (1613)
Sida procumbens Sw. (1532)

LYTHRACEAE

Cuphea procumbens Cav. (1615)
Heimia salicifolia (HBK.) Link (1528)

ONAGRACEAE

Gaura sinuata Nutt. (1635)
Oenothera rosea Ait. (1564, 1636)

UMBELLIFERAE

Sanicula mexicana DC. (1526)

PLUMBAGINACEAE

Plumbago scandens L. (1561)

PRIMULACEAE

Anagallis arvensis L. (1518)
Samolus floribundus HBK. (1550)

CONVOLVULACEAE

Cuscuta indecora neuropetala (Choisy) Hitchcock (1611)
Evolvulus alsinoides L. (1575)
Ipomoea hirsutula Jacq. (1599)

POLEMONIACEAE

Gilia incisa Benth. (1554, 1572, 1573)

HYDROPHYLLACEAE

Nama biflorum Choisy (1515)

BORAGINACEAE

Ehretia anacuna (Berland.) Johnston (1602)

VERBENACEAE

Lantana achyranthifolia Desf. (1569)
Lantana Camara L. (1537)
Lippia reptans HBK. (1587)
Priva mexicana (L.) Pers. (1566)

Verbena canescens HBK. (1571)
Verbena ciliata Benth. (1576)
Verbena Halei Small (1542, 1577)

LABIATAE

Hedeoma Drummondii Benth. (1563, 1618)
Salvia coccinea L. (1574)
Salvia mexicana L. (1513)
Scutellaria Seleriana Loes. (1516)
Teucrium cubense L. (1552)

SOLANACEAE

Bassovia mexicana Robins. (1514)
Capsicum baccatum L. (1606)
Physalis viscosa L. (1612)
Solanum nigrum L. aff. (1557)

ACANTHACEAE

Ruellia Parryi Gray (1579)
Ruellia tuberosa L. (1598)
Siphonoglossa pilosella (Nees) Torr. (1578)
Tetramerium hispidum Nees (1610)

CAPRIFOLIACEAE

Sambucus mexicana Presl. (1523)

RUBIACEAE

Bouvardia ternifolia (Cav.) Schlecht. (1616)
Chiococca pachyphylla Wernh. (1509)
Randia laetivirens Standley (1544)
Spermacoce tenuior L. (1562)

COMPOSITAE

Actinea linearifolia (Hook.) Kuntze (1582)
Astranthium integrifolium (Michx.) Nutt. (1527)
Calyptocarpus vialis Less. (1520)
Dyssodia Berlandieri (DC.) Blake (1630)
Eupatorium odoratum L. (1593)
Gaillardia mexicana Gray (1634)
Helenium amphibolum Gray (1530)
Heterotheca chrysopsidis DC. (1581)
Sclerocarpus uniserialis Benth. & Hook. (1589)
Selloa glutinosa Spreng. (1580, 1640)
Stevia Berlandieri Gray (1626)
Tetragonotheca texana Engelm. & Gray (1583)
Vernonia Ervendbergii Gray (1551, 1628)
Wyethia mexicana Wats. (1624)

UNIVERSITY OF MICHIGAN

VEGETATION OF CERRO DE LA SILLA, NEAR MONTERREY, MEXICO *

STEPHEN S. WHITE

THE present paper is based on three weeks' collecting by Mr. Roy M. Chatters and the writer in August and September, 1937, and on additional collections made by Mr. L. H. Harvey and the writer in the latter part of June, 1939.

CLIMATE

The altitude of Monterrey, capital of the state of Nuevo León, is 528 meters or 1,624 feet. Available meteorological data indicate that extremes of climate are not great (1). The average temperature ranges from a low of 13° C. in December to a high of 28.4° C. in August, and the extremes reported are a maximum of 40° C. and a minimum of − 5° C. Rainfall occurs throughout the year, but is most abundant in September and October, for which an average precipitation of 184 mm. (7.5″) and 115 mm. (4.5″) respectively are recorded. The remainder of the annual precipitation, 648 mm. (25.5″), is distributed among the other ten months, with January receiving only 5.2 mm. and June 64.8 mm. The average annual relative humidity is approximately 63 per cent. These data, based on observations during the five-year period 1921–25, give perhaps a good impression of the general nature of the climate, although such a period is too short to provide entirely trustworthy averages. Indeed, it seems very likely that the climate does not differ materially from that of Laredo, Texas, since the higher altitude compensates for the more southerly latitude.

GEOLOGY

The Sierra de la Silla, extending southeastward from Monterrey, is abruptly terminated at its northern end, just outside the city itself, in the well-known Cerro de la Silla, so named because of its saddle-

* Papers from the Department of Botany and Botanical Gardens of the University of Michigan, No. 717.

like appearance (Pl. I). The peaks rise some 3,500 feet above the plain, which extends northeastward from Monterrey to the valley of the Rio Grande.

Although accessibility is not a problem here, as it is in many other parts of Mexico, scarcely any geological work done in this region has been reported. It has been stated, however, that the rocks are thick-bedded reef limestones of the lower Cretaceous, and the general structure of the region is anticlinal. The surrounding territory is highly mineralized, and a number of mines have been operated here in the past.

HISTORY

References to previous botanical work in this area are found scattered in reports on the collections made in southern Texas and northern Mexico. The first botanist to enter the territory was L. Berlandier, who was commissioned by the Mexican government to report on the nature of the country along the northern border of Mexico (2). The expedition of which Berlandier was a member arrived in Monterrey on January 7, 1828. Two weeks were spent there. His description of the vegetation is made in quite general terms, for he found most of it dormant at that season. He states that he saw in flower, however, many legumes, some composites, a species of Buddleia, a jimson weed, and *Canna indica.* Among cultivated plants growing around Monterrey he mentions cotton, sugar cane, corn, which is harvested twice a year, oranges, limes, and other fruits.

Berlandier was followed by A. Wislizenus and J. Gregg, who accompanied the Doniphan expedition from Chihuahua to Monterrey and back to the United States in 1847 (4). After that time a dozen or more botanists worked near Monterrey. Some of these were Palmer, Parry, Eaton, Edwards, C. and E. Seler, Rose, Canby, and Nelson. Pringle, the best known of all collectors in Mexico, began his extensive travels in 1885, but did not collect near Monterrey until three years later (3). Between 1888 and 1908 he visited Monterrey about eight times to add to his collections.

DESCRIPTION OF THE VEGETATION

At the foot of La Silla there is a small intermittent stream, which at the time of our visits contained only a few pools of water. The course of the stream could be followed in the distance by the trees

which lined its banks. These were *Taxodium mucronatum, Platanus mexicana, Pithecolobium flexicaule,* and *Celtis laevigata.* Most of the herbaceous vegetation was found along the margins of the pools or growing on the dry bottom of the stream. Grasses and sedges were much more abundant here than elsewhere. The grasses, some of them mere weeds, were *Cynodon Dactylon, Paspalum Langei, P. pubiflorum, P. lividum, P. conjugatum, Setaria lutescens, S. geniculata, Echinochloa colonum, Bouteloua filiformis, B. trifida, Triodia texana, T. pilosa, Sorghum halapense, Cenchrus pauciflorus, Aristida Roemeriana, Leptoloma cognatum, Agrostis verticillata,* and *Chloris ciliata.*

Other prominent elements of the vegetation were *Clematis Drummondii, Solanum elaeagnifolium, Ipomoea hirsutula, Nicotiana glauca, Heliotropium procumbens, Lippia reptans, Hydrocotyle verticillata, Baccharis glutinosa, Helenium amphibolum, H. heterophyllum,* and *Tridax procumbens.*

The lower slopes of La Silla are characterized by a growth of microphyllous trees and shrubs which form impenetrable thickets in many places. Here legumes are common, although the number of species is not great. *Caesalpinia caladenia, Acacia Coulteri, A. Farnesiana, A. amentacea,* and *Parosela hospes* are the most common members of the Leguminosae. These, together with the representatives of a number of other families, such as *Cordia Boissieri, Helietta parvifolia, Karwinskia Humboldtiana, Chiococca pachyphylla, Leucophyllum texanum, Ehretia Anacuna,* and *Bouvardia ternifolia,* constitute the dominant vegetation of this zone. The average height of these species probably does not exceed three meters. Although herbaceous plants were here very scarce, low scandent or woody plants were rather common. The most conspicuous of these, in some places at least, was *Mascagnia macroptera.* Lantana was also common; it was represented by four or more species. Other characteristic plants of this zone were *Dyssodia pentachaeta, Vernonia Ervendbergii, Siphonoglossa ramosa, Tetramerium hispidum, Ruellia tuberosa, Jatropha spathulata, Croton monanthogynus,* and *C. fruticulosus.*

Cacti of the pincushion type were abundant in this zone, especially on the ledges formed by the outcropping of the underlying limestone. We secured for propagation in the Botanical Gardens specimens of Mammillaria, Echinocereus, Epithelantha, and Escobaria. Larger forms such as Opuntia were not common.

This type of vegetation extended up the mountain to an elevation of some 3,000 feet. Agaves and similar plants and the palm, *Brahea Berlandieri*, are additional elements of the flora at this elevation (Pl. II, Figs. 1–2). The palm extends some distance into the adjacent oak forest. Among the other plants growing here, but not found at lower elevations, were *Decatropis bicolor*, *Polanisia uniglandulosa*, *Houstonia tenuifolia*, *Cocculus carolinus*, *Cassia Lindheimeriana*, *Sophora secundiflora*, *Bocconia latisepala*, and *Mirabilis Jalapa*.

The upper half of the mountain is mostly covered with a rather dense forest, consisting mainly of three species of oak: *Quercus Canbyi*, *Q. monterreyensis*, and *Q. fusiformis*. The conditions in this forest present a striking contrast to those on the lower slopes. Although scarcely any rain fell during the period in which the collections were being made, it was evident that the upper part of the mountain was more abundantly supplied with water than the lower part. This was doubtless due, in part at least, to the fact that the upper regions were almost daily enveloped in dense cloud banks, especially in the early morning. The most noticeable effect of the relative abundance of water was the luxuriant growth of mosses and ferns. The mosses formed a thick carpet over the rocks and canyon walls, and the ferns, although there were but few species, were plentiful. The species found were *Polypodium polypodioides*, *P. plesiosorum*, *P. guttatum*, *Phanerophlebia umbonata*, *Llavea cordifolia*, *Asplenium resiliens*, *Cheilanthes alabamensis*, and *C. castanea*. *Selaginella cuspidata* and *S. pilifera* were also collected here.

In the oak forest there was a minor element of woody plants made up of *Bauhinia lunarioides*, *Staphylea Pringlei*, *Garrya ovata*, *Vitis Berlandieri*, *Rhamnus serrata*, *Ungnadia speciosa*, *Tilia floridana*, and *Ptelea trifoliata*. Herbaceous vegetation in the deepest part of the forest was almost entirely absent, for only *Parietaria debilis*, *Urtica chamaedryoides*, and *Allium scaposum* were found; in open places, however, the herbaceous flora was well diversified. At the top of the mountain, between the two peaks where the oak forest did not reach, we found dense carpets of *Sedum diffusum*, *Omphalodes acuminata*, and *Lobelia Cliffortiana*. Other prominent plants were *Linum medium*, *Scutellaria suffrutescens*, *Hypericum sp.*, *Erysimum asperrimum*, *Geranium mexicanum*, *Oxalis madrensis*, *Nama biflorum*, *Verbesina coahuilensis*, *Chrysopsis villosa*, *Senecio montereyanus*, and *Encelia sp.* The woody plants were all low shrubs of the following

species: *Philadelphus Coulteri*, *Eysenhardtia texana*, *Colubrina Greggii*, and *Bauhinia lunarioides*. It is of interest to note that the palm *Brahea Berlandieri*, which is common below the oak zone, was also present at the top of the mountain. The elevation at this point between the peaks is 5,200 feet.

Although an attempt was made to collect as large a representation of the flora as possible, the results certainly do not justify any claim that the work has been completed. However, in view of the fact that increasing numbers of botanists are becoming interested in Mexico, it is believed worth while to publish something on what has been accomplished to date, especially since there is no immediate prospect of continuing the work.

All material is deposited in the herbarium of the University of Michigan, with partial duplicate sets in the Gray Herbarium of Harvard University, and in the herbarium of the Instituto de Biología, México, D. F., and the personal herbarium of Dr. Forrest Shreve.

ACKNOWLEDGMENTS

The writer is deeply grateful to Dr. I. M. Johnston for the determination of most of the 1939 collections. For other determinations his indebtedness is as follows: oaks, by Dr. C. H. Mueller; cacti, by Dr. Elzada U. Clover; grasses, by Mr. L. H. Harvey; a miscellaneous group of plants, by Dr. J. W. Moore. Special thanks are due to Professor H. H. Bartlett for much valuable assistance in the preparation of the manuscript.

List of Species

Collection numbers are indicated in parentheses; those of L. H. Harvey are preceded by the letter H.

POLYPODIACEAE

Adiantum tricholepis Fée (82)
Asplenium resiliens Kuntze (H–989)
Cheilanthes alabamensis (Buckl.) Kuntze (H–984, H–990)
Cheilanthes castanea Maxon (H–994, H–995)
Cheilanthes spp. (86, H–1019)
Llavea cordifolia Lag. (152)
Notholaena sinuata (Lag.) Kuntze (H–1012)
Phanerophlebia umbonata Underw. (27, H–996)
Polypodium guttatum Maxon (156, H–992)
Polypodium plesiosorum Kuntze (34)
Polypodium polypodioides (L.) Watt. (20, 22, H–991, H–1016)

SELAGINELLACEAE

Selaginella cuspidata Link (H–997)
Selaginella pilifera A. Br. (H–1018)
Selaginella spp. (H–983, H–988)

PINACEAE

Taxodium mucronatum Ten. (44, 1421)

GRAMINEAE

Agropyron spicatum (Pursh) Scribn. & Smith (H–1013, H–982)
Agrostis verticillata Vill. (H–971, H–977)
Aristida Roemeriana Schult. (H–960, H–968)
Aristida sp. (H–979)
Bouteloua filiformis (Fourn.) Griffiths (H–952, H–972a, H–980)
Bouteloua trifida Thurb. (H–954)
Brachypodium Pringlei Scribn. (H–999)
Bromus spp. (H–985, H–987, H–998)
Cenchrus pauciflorus Benth. (H–967)
Chloris ciliata Swartz (H–976)
Cynodon Dactylon (L.) Pers. (160, H–955)
Echinochloa colonum (L.) Link (187)
Leptoloma cognatum (Schult.) Chase (H–958)
Melica Montezumae Piper (H–981)
Muhlenbergia longiligula Hitchc. (H–986)
Paspalum conjugatum Bergius (H–970)
Paspalum Langei (Fourn.) Nash (167, H–978, H–1028a)
Paspalum lividum Trin. (H–974)
Paspalum pubiflorum Rupr. (188, H–957)
Setaria geniculata (Lam.) Beauv. (H–956a, H–973)
Setaria lutescens (Wiegel) F. T. Hubb (186)
Sorghum halapense (L.) Pers. (H–969)
Triodia pilosa (Buckl.) Merr. (H–966)
Triodia texana S. Wats. (H–953, H–959)

CYPERACEAE

Cyperus sp. (1498)
Eleocharis capitata (L.) R. Br. (70)

COMMELINACEAE

Commelina sp. (1415)

PALMACEAE

Brahea Berlandieri Bartlett (31)

ARACEAE

Xanthosoma robustum Schott (185)

LILIACEAE

Allium scaposum Benth. (29)
Dasylirion sp. (1621)

AMARYLLIDACEAE

Agave sp. (1643)

FAGACEAE

Quercus Canbyi Trelease (33)
Quercus fusiformis Small (1462)
Quercus monterreyensis Trel. & Muell. (1487)

ULMACEAE

Celtis laevigata Willd. (184, 1429)

URTICACEAE

Parietaria debilis Forst. (1489)
Urtica chamaedryoides Pursh (1490)

POLYGONACEAE

Polygonum sp. (180)

AMARANTHACEAE

Amaranthus spinosus L. (63)

NYCTAGINACEAE

Boerhaavia caribaea Jacq. (114)
Mirabilis Jalapa L. (149)

PORTULACCACEAE

Talinum lineare HBK. (1623)
Talinum reflexum Cav. (1622)

PHYTOLACCACEAE

Phytolacca decandra L. (140)
Rivina humilis L. (118)

RANUNCULACEAE

Clematis Drummondii T. & G. (129, 168, 171)

MENISPERMACEAE

Cocculus carolinus (L.) DC. (122)
Cocculus diversifolius DC. (1493)

PAPAVERACEAE

Argemone mexicana L. (1506)
Bocconia latisepala Wats. (151)

CRUCIFERAE

Erysimum asperrimum (Greene) Rydb. (1475)
Lepidium virginicum L. (1441)

CAPPARIDACEAE

Polanisia uniglandulosa (Cav.) DC. (107)

CRASSULACEAE

Sedum diffusum Wats. (1466)

SAXIFRAGACEAE

Fendlera linearis Rehder (1483)
Philadelphus Coulteri Wats. (1470)

PLATANACEAE

Platanus mexicana Moric. (157, 1448)

LEGUMINOSAE

Acacia amentacea DC. (1418)
Acacia Coulteri Benth. (8)
Acacia Farnesiana (L.) Willd. (1417)
Bauhinia lunarioides Gray (32, 1473)
Caesalpinia caladenia Standl. (7)
Cassia Greggii Gray (191)
Cassia Lindheimeriana Scheele (133)
Cassia occidentalis L. (40)
Eysenhardtia texana Scheele (1476)
Parosela hospes Rose (26, 144)
Pithecolobium flexicaule (Benth.) Coulter (36)
Sophora secundiflora (Ortega) Lag. ex DC. (105, 1492)

GERANIACEAE

Geranium mexicanum HBK. (141)

OXALIDACEAE

Oxalis Leonis R. Kunth (125)
Oxalis madrensis Wats. (146)

LINACEAE

Linum medium (Planch.) Britton (145, 1479)

RUTACEAE

Decatropis bicolor (Zucc.) Radlk. (1463)
Helietta parvifolia (Gray) Benth. (2)
Ptelea trifoliata L. (1469)

MALPIGHIACEAE

Malpighia glabra L. (84a)
Mascagnia macroptera (Moc. & Sessé) Niedenzu (3, 1408)

EUPHORBIACEAE

Acalypha dioica Wats.? (68)
Acalypha sp. (11)
Croton ciliato-glandulosus Ort. (1432)
Croton fruticulosus Engelm. (102, 128)
Croton monanthogynus Michx. (93)
Euphorbia pilulifera L.? (1413)
Jatropha spathulata (Ortega) Muell. (6, 1644)
Ricinus communis L. (41, 1405)

SAPINDACEAE

Dodonaea viscosa Jacq. (100, 1647)
Ungnadia speciosa Endl. (1491)

STAPHYLEACEAE

Staphylea Pringlei Wats. (1488)

RHAMNACEAE

Colubrina Greggii Wats. (15, 1472, 1503)
Karwinskia Humboldtiana (Roem. & Schult.) Zucc. (5, 18)
Rhamnus serrata Willd. (1485)

VITACEAE

Vitis Berlandieri Planch. (1486)

TILIACEAE

Tilia floridana Small (1482)

MALVACEAE

Hibiscus cardiophyllus Gray (97)
Sida spinosa L. (99)

STERCULIACEAE

Hermannia texana Gray (1507)

HYPERICACEAE

Hypericum sp. (1474)

FLACOURTIACEAE

Xylosma Pringlei Rob. (111)

PASSIFLORACEAE

Passiflora foetida L. (172)

LOASACEAE

Cevallia sinuata Lag. (1420)
Mentzelia sp. (48)

CACTACEAE

Echinocereus pentalophus (DC.) Rumpler (H–1009)
Echinocereus Viereckii Werd. (221)
Epithelantha micromeris Web. (227, 1457, 1458)
Escobaria Runyonii Br. & R. (1456)
Mammillaria denudata A. Berg. (225)
Mammillaria longicoma Br. & R. (H–1002)
Mammillaria multiceps (Salm-Dyck) Br. & R. (224)
Mammillaria Runyonii Br. & R. (H–1011)
Mammillaria sp. (226)
Opuntia leptocaulis DC. (223)
Opuntia phaeacantha Engelm. (H–1000)

LYTHRACEAE

Heimia salicifolia (HBK.) Link (163, 1437)

ONAGRACEAE

Jussiaea suffruticosa L. (64, 1502)
Oenothera rosea Ait. (56)

UMBELLIFERAE

Hydrocotyle verticillata Thunb. (53, 1422)

GARRYACEAE

Garrya ovata Benth. (1484)

PLUMBAGINACEAE

Plumbago scandens L. (58, 1450)

PRIMULACEAE

Anagallis arvensis L. (1435)
Samolus floribundus HBK. (1499)

APOCYNACEAE

Mandevilla Karwinskii (Muell. Arg.) Hemsl. (115)

ASCLEPIADACEAE

Metastelma angustifolium Turcz. (120)
Vincetoxicum sp. (150)

CONVOLVULACEAE

Evolvulus alsinoides L. (92a)
Ipomoea hirsutula Jacq. (131, 176)
Ipomoea tiliacea (Willd.) Choisy (16, 1468)
Operculina dissecta (Jacq.) House (173)

HYDROPHYLLACEAE

Nama biflorum Choisy (139, 147)
Nama sp. (1410)

BORAGINACEAE

Cordia Boissieri DC. (4, 1404)
Ehretia Anacuna (Berland.) Johnston (1419)
Heliotropium procumbens Miller (1406)
Omphalodes acuminata Wats. (1481)

VERBENACEAE

Lantana Camara L. (60, 1431)
Lantana canescens HBK. (79)
Lantana involucrata L. (1, 74)
Lantana macropoda Torr. (90)
Lantana sp. (24)
Lippia nodiflora (L.) Greene (51)
Lippia reptans HBK. (1409)
Lippia spp. (1496, 1497)
Verbena canescens HBK. (1407, 1442)

LABIATAE

Hedeoma Drummondii Benth. (43, 1423)
Monarda tenuiaristata (Gray) Small (1430)
Salvia ballotiflora Benth. (78)
Salvia coccinea L. (73, 103)
Scutellaria suffrutescens Wats. (155, 1478)
Teucrium cubense L. (46, 1424)

SOLANACEAE

Nicotiana glauca Graham (1403)
Physalis viscosa L. (61)
Solanum elaeagnifolium Cav. (55, 161, 183)
Solanum verbascifolium L. (182, 1494)

SCROPHULARIACEAE

Leucophyllum texanum Benth. (77)
Pentstemon Eatoni Gray (25)
Stemodia durantifolia (L.) Sw. (1436)

BIGNONIACEAE

Tecoma incisa (Rose & Standl.) Johnston (113)

ACANTHACEAE

Jacobinia incana (Nees) Hemsl. (85, 117, 1646)
Ruellia sp. (92)
Ruellia tuberosa L. (1459)
Siphonoglossa pilosella Torr. (52)
Siphonoglossa ramosa Oerst. (1451)
Tetramerium hispidum Nees (1428, 1465)

RUBIACEAE

Bouvardia ternifolia (Cav.) Schlecht. (123, 1460)
Cephalanthus occidentalis L. (71)
Chiococca pachyphylla Wernham (12)
Galium sp. (1414)
Houstonia tenuifolia Nutt. (108)
Randia Watsoni Robinson (10, 1464)

LOBELIACEAE

Lobelia Cliffortiana L. (138, 1480)
Lobelia splendens Willd. (37)

COMPOSITAE

Baccharis glutinosa Pers. (39, 192)
Chrysopsis villosa (Pursh) DC. (132, 1471)
Dyssodia pentachaeta (DC.) Robins. (87, 1508)
Eclipta alba (L.) Hassk. (65)
Encelia sp. (9)
Eupatorium coelestinum L. (194)
Eupatorium odoratum L. (1433)
Gutierrezia eriocarpa Gray (179)
Helenium amphibolum Gray (1445, 1447)
Helenium heterophyllum DC. (1412, 1446, 1449)
Heterotheca sp. (190)
Heterotheca subaxillaris (Lam.) Britt. & Rusby (62)
Parthenium hysterophorus L. (1411)
Selloa glutinosa Spreng. (127)
Senecio montereyanus Wats. (1477)
Tetragonotheca texana Engelm. & Gray (1504)
Tridax procumbens L. (54, 1416, 1444, 1505)
Verbesina coahuilensis Gray (1467)
Vernonia Ervendbergii Gray (121)
Zexmenia hispida (HBK.) Gray (1501)

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View of La Silla from Monterrey (photograph by E. E. Barros)

FIG. 1. Vegetation a little below oak forest

FIG. 2. *Brahea Berlandieri* Bartlett

SEED GERMINATION AND SEEDLING ANATOMY OF SNAPDRAGON (*ANTIRRHINUM MAJUS* L.)

EDWARD F. WOODCOCK

A SURVEY of the literature on *Antirrhinum majus* L. gives no information concerning seed germination and seedling anatomy. Normal cytological processes have been observed in the embryo sac in snapdragon by Propach (2), and Klemm (1) has noted the axile placentation. The morphology of the seed has been described by the writer (3). This paper has to do with a study of some of the tissue changes in seed germination and seedling development of *Antirrhinum majus* L.

MATERIAL AND METHODS

The seeds were germinated in the greenhouse. An interpretation of the changes which occur in the seedling development was obtained by an examination of microtome sections stained with Delafield's haematoxylin. A check on the course of the vascular bundles was gained by observing cleared seedlings.

GERMINATION AND SEEDLING ANATOMY

A brief description of the mature seed will aid in understanding the changes which occur in the early stages of germination. The seed coat consists almost entirely of a single layer of epidermal cells. This uncrushed layer is all that remains of the integument and nucellus. There arise from the outer wall of this layer hairlike outgrowths which are arranged as interconnected ridges. The embryo is a typical dicot type, straight and centrally placed in the starchy endosperm.

In the process of germination the radicle lengthens rapidly to form the primary root. It emerges from the seed through a break in the seed coat, and soon elongates and becomes established in the soil (Pl. I, Fig. 3). The primary meristem regions in the primary root tip are very well marked (Pl. I, Figs. 1–2). The tip of the root is protected by a well-developed rootcap (Pl. II, Fig. 9). The cells of

the dermatogen are distinct from the underlying layer and vary in their tangential dimension. The outer wall of each cell is bulged outward. The periblem is composed of two layers of cells, which are larger than the dermatogen cells and between which occur intercellular spaces. The plerome consists of a peripheral layer of large cells and a central region of small cells.

As germination proceeds further the cotyledons separate from the seed coat and the hypocotyl elongates, which brings the two cotyledons above the soil. The primary root soon produces lateral roots, and the plumule, at the base of the cotyledons, differentiates into a stem bearing opposite leaves.

Numerous anatomical changes occur in the differentiation of the embryo into the seedling. The peripheral cells of the plerome in the root produce a distinct endodermis layer, which later becomes less conspicuous. The central cells of the plerome form the pericycle and the diarch radial bundle (Pl. II, Fig. 1). The pericycle is not easily distinguished from the phloem of the bundle. In the transition region between the primary root and the hypocotyl the vascular tissue becomes so oriented that there are two open collateral bundles in the hypocotyl (Pl. I, Fig. 4; Pl. II, Fig. 4). The course of the vascular bundles through the hypocotyl and the organs above the hypocotyl is diagrammatically shown (Pl. II, Fig. 4). Each of the hypocotyl bundles sends off a branch to each of the cotyledons (Pl. I, Fig. 5). A short distance above these opposite branches each of the hypocotyl bundles again sends off two opposite branches (Pl. I, Fig. 6), which extend for a short distance into the internode between the cotyledon node and first leaf node (Pl. I, Fig. 7). In the base of the internode each of these branches divides again, and a fusion of four of the branches occurs, as shown in the terminal portion of the lower segment of the diagram (Pl. II, Fig. 4). As a result there are eight bundles in the part of the internode directly below the leaf node (Pl. I, Fig. 8). The two bundles which pass out to the petiole of each of the opposite leaves are a continuation of the hypocotyl bundles and divide into three parts as they enter each petiole. Four of the branches, formed in the base of the internode, above the cotyledons, again divide in the leaf node, so that in the internode above the first leaf node there are ten bundles (Pl. I, Fig. 9).

The epidermis of the seedling in the parts above the ground produces gland-tipped and pointed hairs ranging from two to several

cells in length (Pl. II, Fig. 3). Those of the former type are quite generally distributed, whereas those of the latter are not found to any extent on the cotyledons and leaves.

The first leaves (Pl. II, Fig. 7) are oval, and the three bundles in the petiole divide in the blade to form a closely interconnected system of veins. The blade is thin and consists of large loosely arranged mesophyll cells (Pl. II, Fig. 5). The cells of the palisade region differ only slightly from those of the spongy region. Those of the lower and upper epidermis are similar in shape and their radial walls are sinuous in outline when the flat surface of the epidermis is observed (Pl. II, Fig. 2). In the lower epidermis there are typical stomata.

The cotyledons are almost circular in outline, and the two vascular bundles which enter the blade divide to form a system of anastomosing veins (Pl. II, Fig. 8). The epidermis of the cotyledon is similar to that of the leaves, and there is very little evidence of a distinct palisade and spongy region in the mesophyll.

The primary vascular bundles of the hypocotyl and stem consist of phloem, indistinct cambium, and xylem (Pl. II, Fig. 6). The phloem is made up of sieve tubes, companion cells, and parenchyma. The xylem consists of ringed and spiral tracheary tubes and parenchyma. Very little collenchyma and no fibers are present in the hypocotyl and stem of the seedling.

SUMMARY

The seedling produced as a result of the germination of the snapdragon seed has a diarch radial bundle in the root and two open collateral bundles in the hypocotyl. Branching of the bundles occurs in the cotyledon node, resulting in two bundles to each cotyledon and eight bundles in the internode above the cotyledons. Further branching occurs in the region of the first leaf node, and thus forms three bundles to each leaf and ten bundles in the internode above the first leaf. The primary meristems are very distinct in the root tip. Gland-tipped and pointed hairs occur on the parts of the seedling above the ground. The radial walls of the epidermis of the leaves and cotyledon are sinuous in outline. The mesophyll is loosely arranged. The collateral vascular bundles in the stem have no well-marked cambium region.

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PLATES I–II

NOTE

Seedling of *Antirrhinum majus* L.

Figure 4, Plate I, is a diagram. All other figures are drawn with aid of camera lucida. The following abbreviations are used: C, cambium; D, dermatogen; EN, endodermis; EP, epidermis; P, periblem; PA, parenchyma; PE, palisade region; PH, phloem; PL, plerome; R, rootcap; S, spongy region; ST, stoma; T, tracheary tube; W, pericycle.

EXPLANATION OF PLATE I

FIG. 1. Cross section of root tip, showing dermatogen, periblem, and plerome. × 60

FIG. 2. Longitudinal section of root tip. × 28

FIG. 3. Longitudinal section of seedling and seed. × 12

FIG. 4. Cross section of hypocotyl, showing the two vascular bundles. × 18

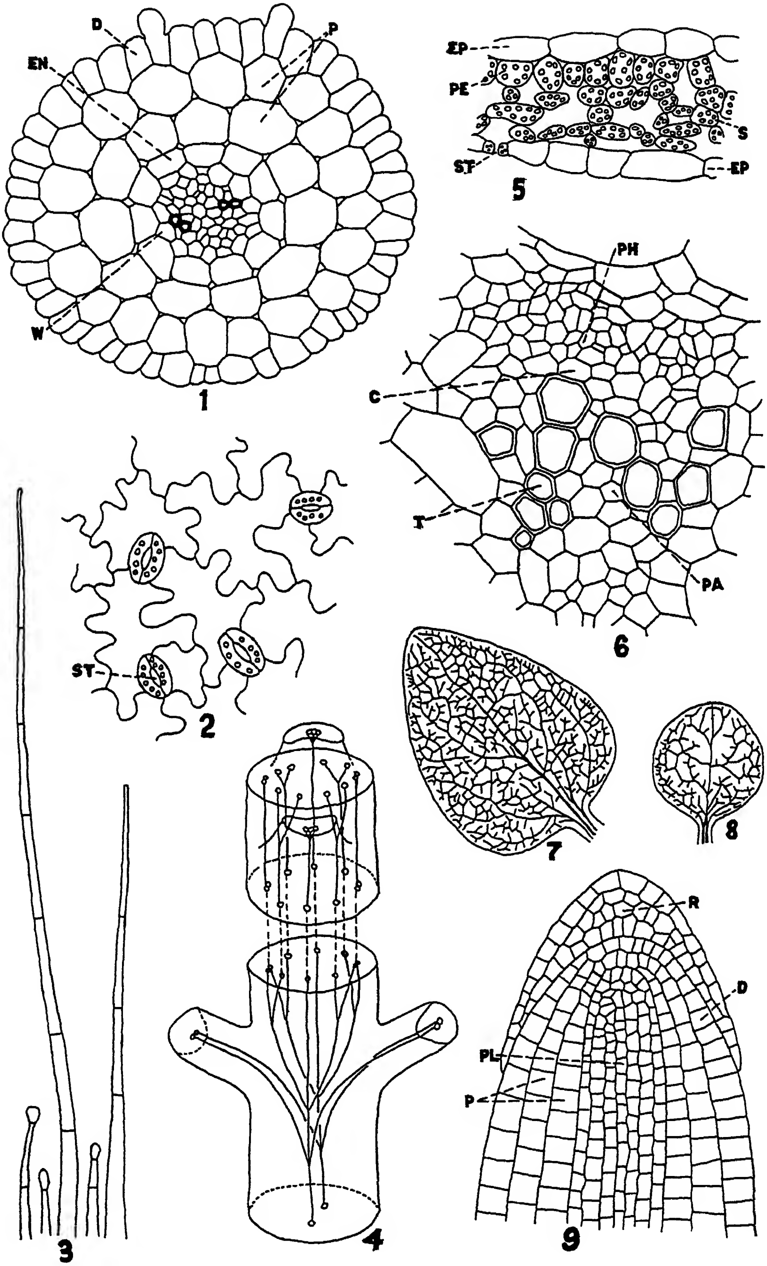
FIG. 5. Cross section of hypocotyl just below cotyledons, showing the two branch bundles which arise from each of the two hypocotyl bundles. × 22

FIG. 6. Cross section of hypocotyl just above region shown in Figure 5. The four branches have passed out into the cotyledons, and the two original bundles have each again sent off two branches. × 16

FIG. 7. Cross section of internode just above the cotyledons. Six bundles are evident in the internode, and two in each cotyledon. × 10

FIG. 8. Cross section of leaf node, showing three bundles passing into the base of each petiole and the formation of the ten bundles in the internode above the first leaves. × 10

FIG. 9. Cross section of internode above the first leaf node. The ten bundles are plainly evident. × 10



Seedling anatomy of *Antirrhinum majus* L.

EXPLANATION OF PLATE II

Fig. 1. Cross section of root tip, showing the epidermis, parenchyma of cortex, endodermis, pericycle, and diarch bundle. × 207

Fig. 2. Surface view of lower epidermis of leaf. × 207

Fig. 3. Hairs on parts of seedling above the ground. × 75

Fig. 4. Diagram showing course of vascular bundles in seedling above the transition zone.

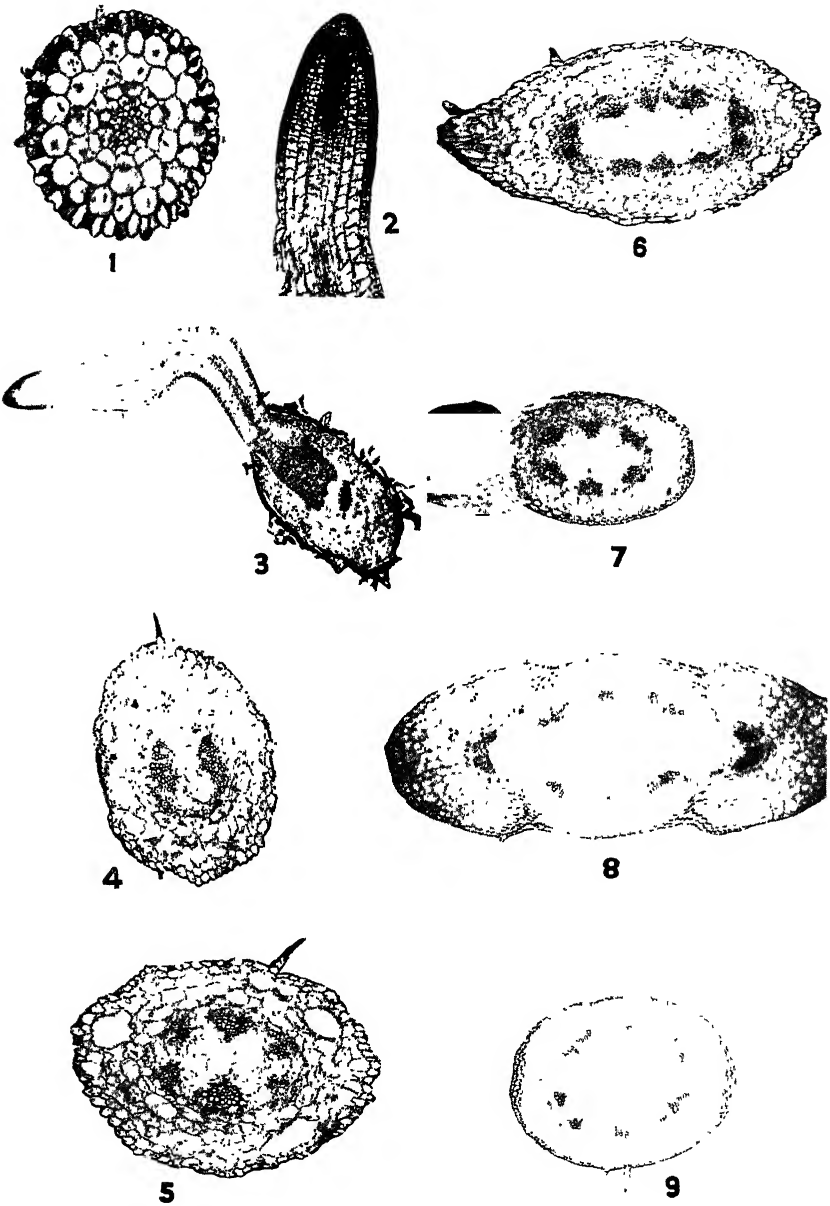
Fig. 5. Cross section of leaf, with loosely arranged mesophyll cells. × 430

Fig. 6. Cross section of one of the vascular bundles in the internode above the first leaf node. × 430

Fig. 7. First leaf, showing shape and venation. × 4

Fig. 8. Cotyledon, showing shape and arrangement of veins. × 4

Fig. 9. Longitudinal section of root tip. Rootcap and primary meristem evident. × 407



Seedling anatomy of *Antirrhinum majus* L.

FORESTRY

SOME RESUPINATE POLYPORES FROM THE REGION OF THE GREAT LAKES. XII

DOW V. BAXTER

FIELD work must necessarily complement studies of authentic types and herbarium specimens. Accordingly, numerous expeditions have been made to various sections of the continent in the effort to secure representative material for this investigation.[1] Many of these plants, reported for the first time in some localities, are from Alaska, the Yukon Territory, and the Northwest Territories. The majority of the American plants have been taken to Europe for comparative study during the course of the work.

This paper reports observations made on seven polypores of North America. Three of the porias are new, *Poria Taxodium*, *P. carnicolor*, and *P. Carnegiea*. *P. Carnegiea* is the first polypore described on *Carnegiea gigantea*, the giant sahuaro.

Poria Taxodium, sp. nov.

(Plate I)

Type:

Poria Taxodium, sp. nov., on *Taxodium distichum*, greenhouse benches, Hillsboro, Illinois. Type. Coll. Dow V. Baxter. Herb. Dow V. Baxter, Ann Arbor.

Planta resupinata, fructificatione annua, tenui, alba, aetate pallide ochracea, late effusa usque ad 30 cm., maturitate planta ex

[1] Throughout the work upon these monographs I am indebted to many individuals and institutions for suggestions, help, and privileges extended to me. My appreciation is expressed particularly to the men who have accompanied me on my several expeditions to Alaska, the Yukon Territory, and the Northwest Territories. Much credit is due them for aiding in the collection and care of the specimens and for living at times under rather difficult circumstances. I am under obligation to Professors T. G. Halle and Gunnar Samuelson of the Naturhistoriska Riksmuséet in Stockholm, with whom I have had the pleasure of association. Thanks are rendered several American institutions and scholars also. To the authorities at the New York Botanical Garden, to Professor H. H. Bartlett, of the University of Michigan, to the staff of the Division of Pathological and Mycological Collections of the United States Department of Agriculture, and to the staff of the Division of Forest Pathology of the same department, I am especially indebted.

substrato separabilis; margine niveo-albo, obscuro, arachnoideo, plerumque 2–3 mm. lato vel angustiore; subiculo tenui, minus quam 0.3 mm. crasso, saepe invisibili; aperturis angularibus, 3–5, plerumque 4–5, in uno mm., primum albis, demum cinnamomeis vel argillaceis; sporis hyalinis, 4–5.5 × 4 μ; hyphis hyalinis, frequenter septatis, saepe ramosis, 2–3 μ in diam., non fibulatis.

Fructification annual, thin, white, becoming cream or tan in age, broadly effused for a distance of 30 cm. or more, mature plants separable from the substratum; margin snow-white, indefinite and arachnoid, mostly not more than 2–3 mm. wide and usually less; subiculum less than 0.3 mm. thick and often invisible; mouths angular, 3–5 mostly 4–5 to a mm., white at first, turning "cinnamon-buff" to "clay-color"; spores hyaline, 4–5.5 × 4 μ; hyphae hyaline, frequently septate, often branched, 2–3 μ in diameter; no clamp connections.

Allied species. — This poria has many of the features of *Poria xantha* or *P. xantha crassa* and might well be mistaken for these plants macroscopically. The spores of the new polypore are, however, 4–5.5 × 4 μ instead of 4–6 × 1–1.5 μ. *P. vulgaris* is likewise suggested, but the spores of that plant, 4–6 × 1–1.5 (2) μ, serve to distinguish them.

Since there have been at least two interpretations of *Poria vaporaria*, one of them designating a plant common to greenhouses, it is necessary to point out their relation to *P. Taxodium.* The plant referred to in this series of monographs as *P. vaporaria* (the polypore of the Swedish pine forests) has spores 4.5–6.5 × 1.5–2 μ. The spores of the other plant, which is called *P. Vaillantii* in this study, measure 5–7 × 3–3.5 μ. Since the spores of this latter fungus, which grows commonly in cellars and hothouses, resemble those of the new species found on cypress greenhouse benches, the two are closely related. They may be distinguished by the fact that *P. Vaillantii* has a rhizomorphic habit of growth and somewhat larger pore mouths. The rhizomorphs of *P. Vaillantii* often become decidedly strandlike or ropelike.

Habitat. — *Taxodium distichum.*

Distribution. — Illinois.

Poria carnicolor, sp. nov.

(Plate II)

Type:

Poria carnicolor on *Tsuga heterophylla,* Priest River, Idaho. Coll. Dow V. Baxter, Sept. 20, 1939. Herb. Dow V. Baxter, Ann Arbor.

Fructificatio annua, carnosa, effusa usque ad 35 cm. in areis elongatis, in speciminibus vivis usque ad 4 mm. crassa, siccitate ca. 2 mm. crassa, demum duriuscula, conspicue salmonicolor vel rubea; margine minus quam 0.3 mm. lato, cito fertili, tubis concolore; subiculo minus quam 0.3 mm. crasso, mox evanescenti; tubis plerumque 1–2 mm. longis, in speciminibus cito siccatis pallide rubeis, colore rubeo persistente, aliter ochraceo vel fusco, in aqua gelatinosis; aperturis 2–3 in uno mm., tubis concoloribus; basidiis plerumque 11–18 × 4–5 μ, 4-sporis; sporis 5.5–7 × 2–3 μ; hyphis 2–4 μ in diam., raro ramosis septatisque, fibulatis.

Fructification annual, fleshy, effused for 35 cm. or more in elongated patches, up to 4 mm. thick when fresh and drying to 2 mm. or less in herbarium specimens, becoming somewhat bony, conspicuous because of its unusual salmon and pink colors but soon attacked by insects so that fruit bodies are seldom found; margin less than 0.3 mm. wide, soon becoming fertile, concolorous with tubes; subiculum less than 0.3 mm. thick and soon disappearing; tubes mostly 1–2 mm. long, "orient pink" to "bittersweet-pink" and mostly remaining pink if dried quickly, otherwise turning "ochraceous tawny" to blackish, becoming somewhat gelatinous when moistened; mouths 2–3 to a mm., concolorous with tubes; basidia mostly 11–18 × 4–5 μ, 4-spored; spores 5.5–7 × 2–3 μ; hyphae 2–4 μ in diameter, seldom branched and seldom septate; clamp connections present.

Habitat. — *Tsuga heterophylla.*

Distribution. — Idaho.

Decay. — It is difficult to ascribe certain types of decay to a fungus found on old logs in the forest, since the rot observed may be due to an entirely different plant. The rot directly beneath the fruiting body of this poria is chalky white and the affected wood, white because of the presence of mycelium, rubs off in the fingers, much as does the fruiting body of *Fomes laricis.* Thin

flat sheets of white mycelium appear in the wood and have a "soapstone" feeling when handled.

Remarks. — This is one of the most colorful, if not the most colorful, of all the porias.

Poria Carnegiea, sp. nov.

(Plate III)

Type:

Poria Carnegiea on bundles of *Carnegiea gigantea* (Engelm.) Britton and Rose. Coll. Dow V. Baxter, Tucson, Arizona, July 14, 1938. Herb. Dow V. Baxter, Ann Arbor.

Fructificatio annua, primum arachnoidea, tenuis, 1–3 mm. crassa, effusa in areis non longioribus quam 15 cm., plerumque ca. 5–7 cm. longitudine, 1–1.5 cm. latitudine; margine arachnoideo, obscuro, plerumque ca. 3–4 mm. lato, albido; subiculo albido, minus quam 0.3 mm. crasso; tubis primum albidis, aetate siccitateque cinnamomeis vel argillaceis vel brunneis, 0.5–2 mm. longis; aperturis cum tubis concoloribus, angularibus, fimbriatis, 1–5, plerumque 3–4, in uno mm., mox coalescentibus et crescentibus; basidiis plerumque ca. 9–11 × 3–4 μ; sporis 4 × 2–3 μ; hyphis hyalinis, interdum septatis, sparse ramosis, fibulatis.

Fructification annual, arachnoid at first, thin, 1–3 mm. thick, effused in patches mostly not longer than 15 cm. and usually about 5–7 cm. in length and 1–1.5 cm. wide; margin arachnoid, indefinite, mostly 3–4 mm. wide, whitish; subiculum whitish, less than 0.3 mm. thick; tubes whitish at first, drying to "cinnamon-buff," or "clay-color" to "Sayal brown," 0.5–2 mm. long; mouths concolorous with tubes, angular, fringed, 1–5 mostly 3–4 to a mm. but soon coalescing and becoming larger; basidia mostly 9–11 × 3–4 μ; spores 4 × 2–3 μ; hyphae hyaline, occasionally septate, not much branched; clamp connections present; no cystidia.

Allied species. — The white margin of this plant and the thin nature of the fruiting body might suggest *Poria vulgaris,* but the two may be distinguished by the fact that the spores of *P. vulgaris* are 1–1.5 × 4–6 μ, whereas those of *P. Carnegiea* are 4 × 2–3 μ. Furthermore, the tubes of *P. Carnegiea* often coalesce and the mouths become much larger than those of *P. vulgaris.*

Remarks. — This plant is the first poria described on cactus. It grows on the giant sahuaro, but has been overlooked partly be-

cause of the relatively limited distribution of the host and partly because it is not found on the outside of the fallen plant, as is usual with other resupinates. *Poria Carnegiea* grows on the bundles of the cactus, so that the outer part of the plant must be pulled away or torn apart before the fungus is discovered. There is evidently more moisture and a cooler temperature on the interior of the sahuaro, factors which undoubtedly favor the growth of *P. Carnegiea* on the bundles rather than on the outside.

Fuscoporia juniperina Murrill, North Am. Fl., 9, Part 1: 4–5. 1907

(Plate IV, Figures 1–2)

Type and important specimen:

Fuscoporia juniperina on fallen trunks of *Juniperus virginiana*, Dec. 3, 1888. A. B. Langlois 1584. Herb. New York Botanical Garden, New York.

Fuscoporia juniperina on *Taxodium distichum*, Arkansas. Coll. Dow V. Baxter, 1933. Herb. Dow V. Baxter, Ann Arbor.

Fructification effused for 14 cm. or more, inseparable, coriaceous to woody, mostly 1.5–4 mm. thick; margin sterile, mostly less than 1 mm. wide, "snuff-brown"; subiculum up to 0.5 mm. thick, concolorous with tubes; tubes in one or two layers, "snuff-brown" to "bister," up to 5 mm. long but mostly 1 mm. or less; mouths mostly 6–7 to a mm., "Dresden brown," "snuff-brown," "bister" or "Natal brown"; dissepiments thick, entire; spores globose, smooth, hyaline, 5–6 μ (Murrill); cystidia rare (Murrill); no setae.

This plant when young resembles *Poria ferruginosa* and might well be mistaken for it in one-year growth forms. The type specimen and also other and older specimens appear more woody than *P. ferruginosa* ever does, and in the woody condition the species suggests a young form of *Fomes igniarius laevigatus* in color and texture. The reddish brown ("Natal brown") of old plants and of bruised parts even of many young forms is characteristic for the species. Although the tubes often occur in layers, the plant is relatively thin compared to *F. igniarius laevigatus*.

Habitat. — *Juniperus virginiana, Taxodium distichum.*

Distribution. — Arkansas, Louisiana.

Decay. — *Fuscoporia juniperina* causes a white laminated sap rot in

Taxodium (Pl. IV, Fig. 2). Fine brown lines appear throughout the decayed wood, which separates in thin paper-like sheets.

Daedalea juniperina Murrill, North Am. Fl., 9, Part 2:125. 1908

(Plate V)

Agaricus juniperinus Murr., Bull. Torr. Bot. Club, 32:85. 1905.

Fructification corky, sessile, attached by a broad, frequently decurrent base, pileate specimens imbricate, pilei 2–5 × 2–10 × 1.5–3 cm.; surface finely tomentose to nearly glabrous, "pinkish buff" to "cinnamon-buff" or "cinnamon-brown," becoming blackish at base or in older specimens; margin becoming fertile, mostly "pinkish buff"; context corky, "pinkish buff," concentrically banded, 0.3–1 cm. thick; furrows labyrinthiform, 0.5–2 cm. long, 1–3 mm. wide, mostly "cinnamon-buff," edges often becoming irpiciform; spores cylindric, smooth, hyaline, 2–3 × 5–7 μ; hyphae hyaline, 3–7 μ; no cystidia.

Allied species. — Resupinate specimens may suggest *Trametes Peckii* Kalch., but the spores of *T. Peckii* are much longer and measure 12–15 × 4 μ. *T. Peckii* is most common on willows and poplars, whereas *Daedalea juniperina* occurs most often on juniper. Some specimens bear a resemblance to *D. quercina*, but the context is lighter in color in *D. juniperina* and the plants do not become so large as those of the hardwood-inhabiting plant.

Irpex Galzini Bres. grows on juniper also and this plant may be even more difficult to separate from *Daedalea juniperina*, although there are no records of it from America. *I. Galzini* is somewhat more fragile than the Daedalea and its spores are "4.5–5.5 × 1–1.5 μ" (B. & G.) (Pl. VI).

Well-developed specimens which have dark pilei may resemble young *Fomes juniperinus*, for even when young the upper surface of *F. juniperinus* is brown, with numerous cracks, and becomes almost black and very rough, as does the surface of *Daedalea juniperina.*

Habitat. — *Juniperus utahensis, J. virginiana.*

Distribution. — Arizona, Kansas, Kentucky, Missouri, Oklahoma.

Polystictus cuneatus, comb. nov.

Coriolellus cuneatus Murr., North Am. Fl., 9: 28. 1907.

Type and important specimen:

Coriolellus cuneatus Murr. on bark of "giant cedar," British Columbia, Aug., 1887. Coll. John Macoun 60. Herb. New York Botanical Garden, New York.

Polystictus cuneatus on *Thuja plicata*, Vancouver, British Columbia, Aug. 22, 1932. Coll. Dow V. Baxter. Herb. Dow V. Baxter, Ann Arbor.

Fructification on bark of logs, posts, and dead standing trees, thin, flexible, cuneate to dimidiate, imbricate, or often resupinate-reflexed or resupinate, sometimes extending two or more meters over the substratum; surface villose to strigose, azonate, mostly 1–2 mm. thick; tubes white to "cream-buff," 1 mm. or less in length; mouths 1–3 mostly 2 to a mm.; dissepiments thin, dentate-lacerate, becoming irpiciform; spores smooth, globose, hyaline, 3–4 μ.

Allied species. — This plant is readily distinguished from other species in the Polystictus group. The flexible or pliable nature of the fruiting bodies when old may suggest weathered *Polystictus abietinus* but the color of even the old pores as well as the surface of the pileus of *Pol. cuneatus* remains whitish or cream. The pores and the surface of the pileus are often concolorous in *Pol. cuneatus*, but in *Pol. abietinus* the pores in age may change from a pink or violet shade to brownish, and generally they are not concolorous with the surface of the pileus.

Habitat. — *Thuja plicata.*

Distribution. — British Columbia, Washington.

Occurrence. — This plant grows abundantly in southwestern British Columbia. It is common particularly on rustic timbers of the western red cedar, where the bark has not been removed, and likewise abundant on small dead trees in the forest. The fungus is often overgrown with moss.

Fomes annosus (Fr.) Cooke, Grevillea, 14: 20. 1885

(Plate VII)

Polyporus annosus Fr., Syst. Myc., 1: 373. 1821.
Polyporus serpentarius Pers., Myc. Eur., 2: 82. 1825.
Polyporus subpileatus Weinm., Syll. Pl. Nov., 2: 102. 1827.
Polyporus resinosus Rostk. in Sturm, Deutsch. Fl., 4: 61. 1830. Non (Schrad.) Fr. 1821.
Trametes radiciperda R. Hartig, Wicht. Krankh. Waldb., p. 62. 1874.

Fomitopsis annosa (Fr.) Karst., Rev. Myc., 3: 18. 1881.
Polyporus Gillotii Roum., Gillot, Rev. Myc., 4: 234, Pl. 32. 1882.
Heterobasidion annosum (Fr.) Bref., Unters. Gesammt. Myk., 8: 154. 1889.
Polyporus irregularis Underw., Bull. Torr. Bot. Club, 24: 85. 1897.
Ungulina annosa (Fr.) Pat., Ess. Tax. Hymen., p. 103. 1900.

Fructification perennial, effused-reflexed, appearing above ground at base of coniferous trees or often resupinate on underneath side of roots of upturned or tipped trees or on exposed roots, mostly applanate, coriaceous or woody, very irregularly lobed; pileus 4.5–14.5 × 3.5–17 × 0.5–3.5 cm.; surface velvety to nearly glabrous, rugose, zonate, more or less encrusted, new growth "pinkish buff," "Verona brown" to "warm sepia," becoming "chestnut-brown" to blackish; margin entire to wavy, at first white and becoming brown; context "light buff," corky, 1 cm. thick or less, upper part forming a dark horny pellicle; tubes "light buff" to "pale ochraceous buff," frequently in a single layer indistinctly and unevenly stratified, layers loosely held together and often separating, many old tubes stuffed, 2–20 mostly 2–7 mm. long each season; mouths whitish, 2–3 to a mm.; basidia 30–40 × 8–10 μ (Hiley), 2- to 4-spored; spores hyaline, smooth, ovoid, 4–6 × 3–4 μ (Shope); hyphae of context (pellicle) seldom branched, 1–3 μ in diameter; no cystidia; conidia seldom occurring in nature but appearing on fructifications kept in damp chambers, capable of producing new mycelia while still on conidiophore; conidiophores usually developing in cultures and often appearing in large bundles approximately 5 mm. in length, sometimes swelling at apex and cutting off numerous conidia or under favorable conditions branching and forming coremia (2).

Allied species. — Because *Fomes annosus* is commonly resupinate, it is often labeled Poria by collectors and is sent to me for determination of the species under that genus. It is also not unusual for it to be called Trametes. Actually, the fungus became well known to European foresters as *Trametes radiciperda* because of the classical studies of Robert Hartig (5). There are no porias which are closely related to *F. annosus*. *T. serialis* differs in its habit of growth and can be distinguished by the fact that its margin is not at all wavy or lobed. *Microscopically*, *F. annosus* differs from *T. serialis* in many of its features. The spores of *F. annosus* are ovoid, 4–6 × 3–4 μ, whereas those of *T. serialis* are cylindric-ellipsoid, 7–9 × 2–3 μ.

Fomes annosus is more likely to be confused with *F. applanatus* (on conifers) and *F. pinicola* when these two fungi occur in the resupinate state than it is with *Trametes serialis.* As a matter of fact, *F. applanatus* and *F. pinicola* are sometimes difficult to separate when these forms occur in the very wet coastal forests of British Columbia and Alaska, even when a pileus is present. The context in *F. applanatus* is brown (dark brown in typical specimens), but it is whitish or yellowish white in *F. annosus.* The mouths of *F. pinicola* darken when bruised more conspicuously than do those of *F. annosus.* The fact that the upper part of the context in *F. annosus* forms a dark thin pellicle should aid in distinguishing it. The spores of *F. applanatus* are brown; those of both *F. annosus* and *F. pinicola* are hyaline.

Because the tubes of *Fomes annosus* are often in one layer and because its context is corky and its spores subglobose, the plant has been confused with the white forms of *Pol. unitus* (*Poria medulla-panis*). The much-branched mycelium in *Pol. unitus* and its more or less regular (not wavy) marginal characteristic should enable one to distinguish the two species.

Habitat. — *Abies amabilis, A. concolor, A. grandis, A. lasiocarpa, A. magnifica shastensis, Acer macrophyllum, Castanea dentata, Chamaecyparis thyoides, Diospyros virginiana, Juniperus virginiana, Larix occidentalis, Picea Engelmannii, P. rubra, P. sitchensis, Pinus caribaea, P. contorta, P. echinata, P. glabra, P. monticola, P. muricata, P. palustris, P. ponderosa, P. resinosa, P. rigida, P. Strobus, P. taeda, P. virginiana, Populus balsamifera, P. trichocarpa, Pseudotsuga taxifolia, Quercus prinus, Q. utahensis, Sequoia sempervirens, S. washingtoniana, Thuja occidentalis, T. plicata, Tsuga canadensis, T. heterophylla.*

Distribution. — British Columbia, Alabama, Alaska, Arizona, Arkansas, California, Colorado, Connecticut, District of Columbia, Florida, Idaho, Indiana, Iowa, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, New Jersey, New Mexico, New York, North Carolina, Oregon, Pennsylvania, Rhode Island, South Dakota, Virginia, West Virginia, Washington, Wisconsin.

Occurrence. — *Fomes annosus* is distributed throughout the North Temperate Zone and is especially prevalent in Europe. In North America it is common as a saprophyte and is known to cause butt

rot, especially in living juniper, red spruce, white pine, and pitch pine in the East. It is often reported in the Douglas fir–hemlock forests of the Pacific Northwest and I have made abundant collections of it on western hemlock in the Tongass National Forest in southeastern Alaska. *F. annosus* is not a serious pest there.

Both European and American investigators have suggested that possibly various strains of the fungus exist and that the form or forms of *Fomes annosus* most prevalent in the United States at least differ with reference to their parasitism from the form or races abroad. The fact that practically all the American conifers introduced into Europe have been attacked and actually damaged by the fungus in plantations there gives rise to the belief that physiologically the American fungus differs from the European species (11).

Fomes annosus occurs rarely on structural timbers except in mines, although I have found it fruiting on a Scotch pine fence post in Sweden. The fungus, however, is usually observed on roots, stumps, or at the base of standing or tipped trees or snags in the forest. It is, of course, to be seen on the roots of recently wind-felled trees. *Trametes serialis,* on the other hand, is most common on logs of trees which have been down for longer periods and on lumber, occurring abundantly on basal logs in cabins throughout much of northern North America and on heavy structural timber.

Decay. — Coniferous wood infected with *Fomes annosus* becomes pink or lilac in the incipient stages of decay and then turns yellow or brown. When the wood becomes visibly decomposed numerous pockets lined with white fibers or white mycelium occur, and a black spot appears in the pockets, which coalesce so as to form large masses of white spongy fibers. On the ends of logs the rot appears in rings because of the more rapid destruction of the springwood. Roots are attacked first.

In trees with low resin content the decay frequently extends several feet up the trunk, but in those conifers with high resin content the rot is usually confined to the butt (7).

Importance of decay and methods of handling infested stands. — In European countries this root-decaying fungus (together with *Armillaria mellea*) is considered among the most serious causes of failure in forest plantations. Likewise, it does much damage in

the natural forests. In Germany, for example, Falck (3) reports that the loss in value of fir varies from 8 to 21 per cent as a result of this fungus. "There is much to indicate that it is much more noxious in Denmark," according to Lind (8), "than in neighboring countries, — half of all Danish firs are destroyed by it."

Infection varies somewhat with the age and species of trees. Douglas fir, Lawson's cypress, and white pine are prevalently attacked when young, according to Hiley (6), whereas larch, spruce, and Scotch pine exhibit rot most generally when old. Although in Europe I have seen *Fomes annosus* on trees of less than ten years' growth, the fungus seems to be commonest in older ones. I have observed spruce trees in Sweden and elsewhere in Europe in which only the heartwood had been attacked. In young and old trees decay in the sapwood, the heartwood, or in both is common. Old trees are usually not killed unless suppressed, but since they are weakened by rot much of their value is lost in windfall.

The group system or a combination of the group and the strip systems is practiced in many forests abroad in the effort to avoid clear-cutting and to create an all-aged forest in the future. The infected timber is salvaged if possible. Mixed stands, particularly if beech or other hardwoods are the associated species, are less likely to be damaged seriously than are pure forests.

In America it has not been so generally necessary to inaugurate special silvicultural practices in the forest because *Fomes annosus* seldom causes much damage here. In the eastern United States, however, there are many reports of it both in plantations and in the natural forest. The fungus is prevalent, for example, in the historic forest plantations at Biltmore, North Carolina (4), and it is likely to become a serious pest in other plantations as they grow older. In certain California forests, too, Meinecke (9) predicts that it will become more abundant. These beliefs are based in part at least on the present treatment of the natural stands during logging operations, their frequent subjection to fire, and the deterioration of the forest sites as a result of such abuse, as well as on the expectation of a larger proportion of older plantations than we now have.

Anderson (1), who made extensive investigations in Scotland, reports that the fungus was "originally a purely saprophytic

type" and was confined to dead material, such as old roots, stumps, and fallen branches. Conifers were in demand there and were planted on sites unfavorable for their growth. Since the fungus is capable of attacking trees under such circumstances, and since the area is already so contaminated, conditions seem more conducive to its spread.

Fomes annosus is the indirect cause of some windfall in both eastern and western American forests. Although it has been observed on fence posts and dead timber, it does not play an important part in the destruction of slash over wide areas. It often rots coniferous props in mines, however, and is in some localities a prevalent cause of decay in such timbers.

Poria vaporaria Fr., Hymen. Eur., p. 379

Poria sinuosa-vaporaria Fr. *sensu* Romell. Svensk Botanisk Tidskrift, 20: 21. 1926.
Polyporus sinuosus Fr. *sensu* Romell, Bresadola. Svensk Botanisk Tidskrift, 20: 17. 1926.
Poria silvestris in Swedish literature.

Type, cotypes, and important specimens:

Poria sinuosa Fr. typica! 35. Eichler. Herb. of Bresadola, Stockholm.
Polyporus vaporarius Fr., f. *regularis*, ex Karsten. Herb. of Bresadola, Stockholm.
Polyporus vaporarius Nattavara, 1910. Hymen. Lapp. Herb. Mycolog. Lars Romell, Stockholm.
Poria sinuosa, ex Herb., J. R. Weir 10784. Herb. Mycolog. Lars Romell, Stockholm.
Poria Friesii Romell. Leg. Seth Lundell. Herb. Mycolog. Lars Romell, Stockholm.

Fructification annual, somewhat coriaceous even when fresh, effused in elongated patches usually up to 35 cm. or more, about 1–2 mm. mostly 1.0 mm. thick, separable from the substratum in small pieces when fresh; margin appressed, fimbriate, up to 1 mm. wide, whitish, "pinkish buff," becoming fertile; subiculum less than 0.5 mm. thick, "pinkish buff"; tubes 0.5–2 mm. long; mouths 1–3 mostly 1–2 to a mm., whitish "ivory-yellow" to "pinkish buff" when fresh, drying to "clay-color" and sometimes "Sayal brown"; dissepiments mostly 130–310 μ thick, somewhat dentate; basidia 4-spored, 18–21 $\times$ 4.5–7 μ; spores nonguttulate, cylindrical or allantoid, 4–6 (4–5.5 $\times$ 1) 1–2 μ; hyphae 1.5–2.5–3 μ in diameter, seldom septate, much branched; clamp connections present.

Allied species. — Many white or whitish plants have been placed under the name *Poria vaporaria*. *Polyporus versiporus* was, for example, referred to both *P. vulgaris* and *Pol. vaporarius* by Fries. Romell (10) believed that *P. sinuosa* and *P. vaporaria* as interpreted at first by himself and Bresadola were, in all probability, identical plants.

The species of Fries, according to Romell and other European authorities, is entirely different from *Poria vaporaria* in the sense of Hartig, Hennings, Rostrup, and Metz. The plant of Fries grows "*in pineto-montanis*," with spores 4.5–6 × 1.5–2 μ, whereas the other poria, which grows commonly in cellars, hothouses, and so on, has elliptical spores 5–7 × 3–3.5 μ. I have collected the Swedish plant around Stockholm and Uppsala and elsewhere in the Scandinavian countries, usually on coniferous pine logs in the forest. Here the fungus occurs more frequently than it does in America. It is especially common in timberlands similar to the lodgepole pine forests of the American West.

At least two distinct plants are known as *Poria vaporaria*, and many others have been so labeled in herbaria. It is true that Romell suggested the new name *Polyporus Friesii* for the Friesian species in order to separate it from the species of Persoon (the plant found in cellars). Bresadola, however, used the name *P. Vaillantii* for the fungus which appears to be that of Persoon. Bourdot and Galzin have retained the name *P. vaporaria* for the Swedish plant of the woods with spores "4–6 × 1–2" μ and usage has seemed to establish this name for that species. Though somewhat contrary to rules, it seems therefore both the sensible and by far the most practical procedure to refer the name *P. Vaillantii* to the white plant of Persoon (a cellar plant with spores 5–7 × 3–3.5 μ and usually rhizomorphic) and retain the name *P. vaporaria* for the fungus which occurs so commonly in the Swedish forests, not ropy and with spores 4.5–6.5 × 1.5–2 μ.

Young specimens of *Poria vaporaria* (as recorded near Uppsala, in the field) might at first be mistaken for the more whitish forms of *P. xantha*, but a critical examination will readily reveal the differences in pore sizes. Even in young specimens, the pore mouths of *P. vaporaria* are larger and often appear daedaloid under the hand lens.

Old specimens of *Poria vaporaria* may suggest *Trametes serialis*,

but can be separated by their different spore characters. *T. serpens*, also, has been called *P. vaporaria* but may likewise be distinguished on the basis of spore characteristics.

Habitat. — *Abies balsamea, Larix occidentalis, Picea Engelmannii, P. glauca, P. mariana, P. sitchensis, Pinus banksiana, P. caribaea, P. contorta, P. lambertiana, P. monticola, P. ponderosa, P. Strobus, P. radiata, P. rigida, Pseudotsuga taxifolia, Thuja occidentalis, Tsuga heterophylla, T. mertensiana.*

Distribution. — Alberta, Northwest Territories, Ontario, Quebec, Yukon Territory, Alabama, Alaska, California, Georgia, Idaho, Michigan, Minnesota, Montana, Nebraska, New Hampshire, New Jersey, New York, Oregon, Pennsylvania, Washington.

Decay. — The fungus produces a dry cubical brown rot in coniferous logs in the woods. It occurs chiefly on the larger slash in the forest.

The literature is confusing in respect to the damage caused by this fungus, since the species called here *Poria Vaillantii* has been designated often in reports by various authors as *P. vaporaria. P. Vaillantii* is found in basement timbers and causes a rot similar to that of *Merulius lacrymans.*

The Swedish plant named in the present studies *Poria vaporaria* is not the same *P. vaporaria* designated by Gäuman in the well-known studies on the rate of decay in timber felled at different seasons of the year. The spores of his plants measure "4–6 × 3–5" μ or "5–7 × 4–6" μ. This interpretation of *P. vaporaria* is perfectly understandable in view of the confusion that exists in the literature regarding the species. Gäuman's *P. vaporaria* is actually *P. versipora* (Pers.) Romell.

University of Michigan

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PLATES I–VII

Poria Taxodium, sp. nov., on *Taxodium distichum*, Hillsboro, Illinois

Poria carnicolor, sp. nov., on *Tsuga heterophylla*, Priest River, Idaho

Poria Carnegiea, sp. nov., on *Carnegiea gigantea*, Tucson, Arizona

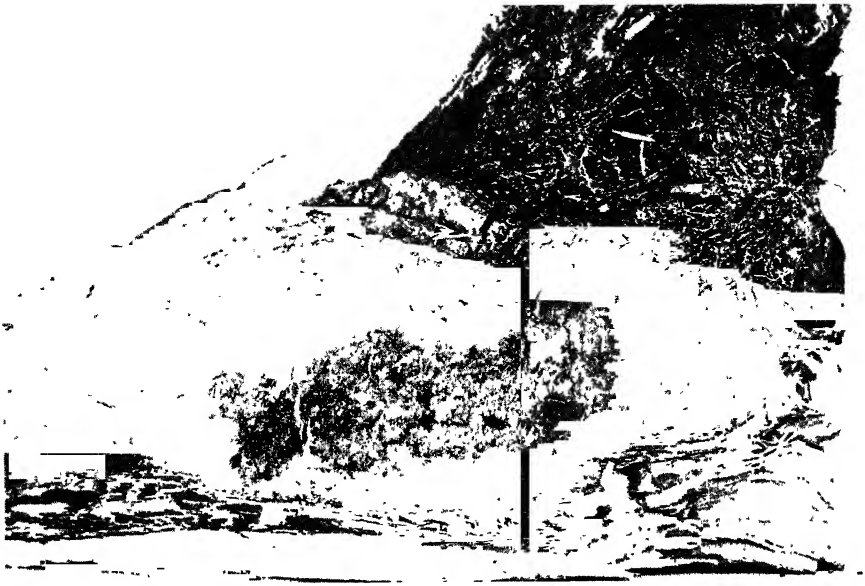


FIG. 1. *Fuscoporia juniperina* Murr. on *Taxodium distichum* from Arkansas

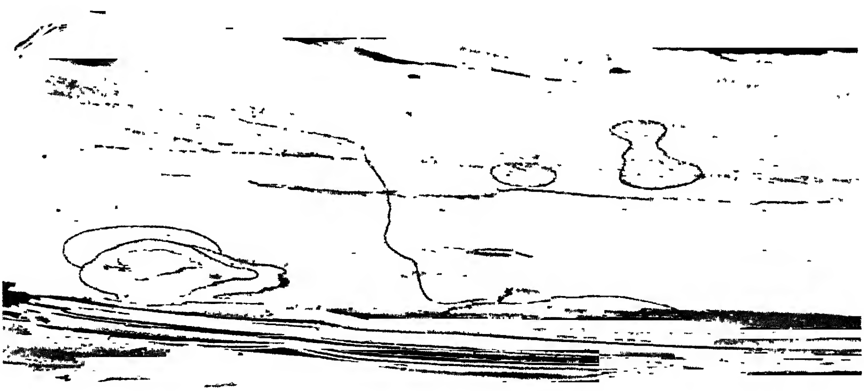
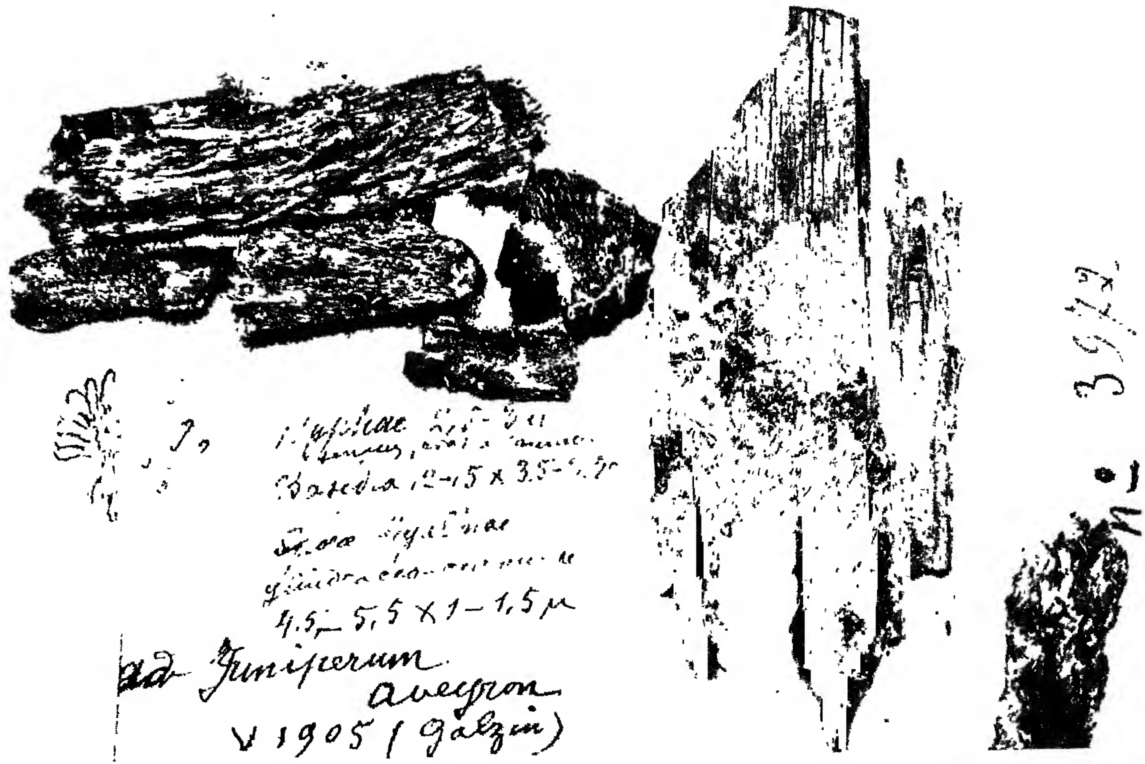


FIG. 2. Sap rot of *Taxodium distichum* caused by *Fuscoporia juniperina* Murr.

Daedalea juniperina Murr. on *Juniperus utahensis*, Sedona, Arizona. Coll. W. H. Long



Irpex Galzini Bres. Coll. Galzini, Bresdola herbarium, Stockholm, Sweden

Fomes annosus (semiresupinate form) on *Tsuga heterophylla*, Sitka, Alaska

GROWTH ON CUTOVER SPRUCE-FIR PULPWOOD LANDS IN NORTHERN MICHIGAN

ARTHUR B. BOWMAN

INTRODUCTION

SPRUCE and fir stands in northern Michigan probably offer greater opportunity for the practice of forest management than any of the other forest types in this region, because of the relatively short rotations and cutting cycles upon which they can be operated. Owing to their comparatively low fire hazard they are also safer investments. Despite these advantages forest management has not progressed, or even gotten a fair start, since we know so little about the growth and yields of the major pulping species, of the probabilities of renewing them after cutting, of the factors accounting for windfall, mortality, and losses from logging, of proper slash-disposal methods, and a host of other problems. A comprehensive study designed to furnish an answer to some of these questions has been under way at Michigan State College for several years. It is hoped that by the end of the coming field season (1940) sufficient data will have been gathered to enable us to complete the analysis of the whole project and to issue a bulletin on it. Thus far results are available only on cutover areas.

ANALYSIS OF GROWTH

Through the efforts of several field crews data on about 90 cutover plots have been gathered. They relate to material removed at the time of cutting, material left after logging, growth of sample trees, quantity and condition of the reproduction, and various other factors such as vegetative cover, timber type, density, soil type, drainage, date of logging, and history of the area. A preliminary investigation disclosed that some of the plots were abnormal and had to be eliminated; in the end only 83 plots remained for further analysis. These plots represented, however, just about every conceivable condition, from very light to very heavy removals and from recent to relatively

old cuttings. Some represented areas that had been cut over more than once. Diverse as the conditions were, it was felt that the growth trends would be more strongly defined by creating additional new plots from the original ones. Consequently, each plot that had been cut over 15 or more years served to produce at least one new plot by reconstruction of the stand at 10-year intervals after cutting. As an example, data from an area cut over 28 years ago served to

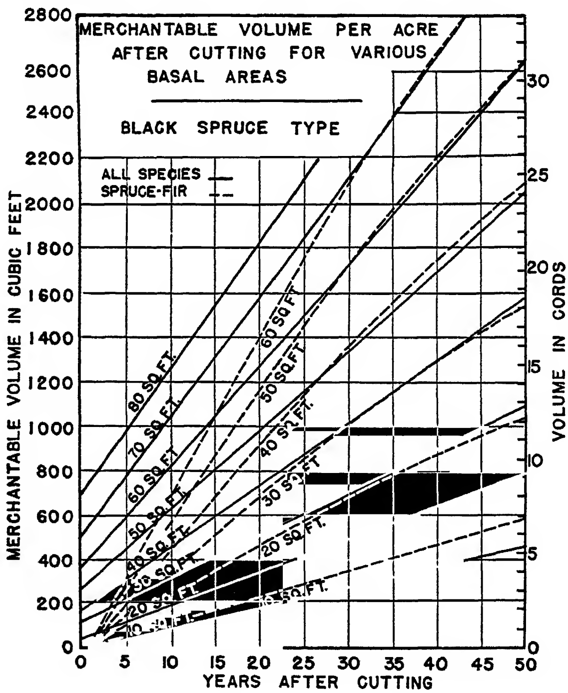


FIG. 1

produce data for 10 and 20 years after cutting. Increment borings and a record of mortality losses facilitated this determination. This method of acquiring "new plots" is perfectly sound and legitimate, and is followed in most growth studies of this nature. Furthermore, it is believed to be fairly reliable in view of the many borings taken — some 1,800. Altogether, 88 new plots were created, which, with the original ones included, were divided among three different forest types as follows:

Black spruce	68
White spruce–balsam fir–paper birch	68
Northern white cedar	35
Total	171

It was obvious at the outset that the three most important factors affecting stand volume after cutting were site quality, quantity of growing stock that was left, and the elapsed time. It was also obvious

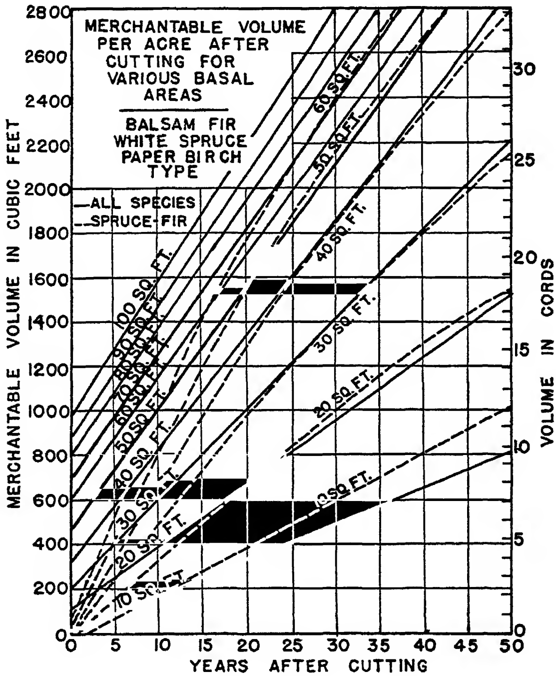


FIG. 2

that the plots should be separated on this basis if the influence of each factor was to be ascertained. Instead of separating the plots into site qualities, however, which would have presented unusual difficulties at the time, they were simply segregated by former forest types; close correlation between type and site was implied. With the plots classified in this manner it was necessary only to select some graphic method of averaging plot volumes by the use of two factors, residual basal area and number of years after cutting, as independent vari-

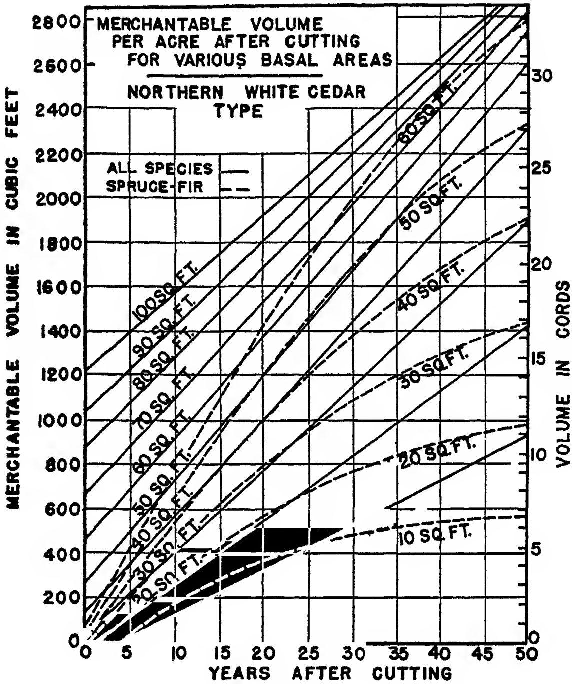


FIG. 3

ables. Residual basal area was employed as an independent variable instead of residual merchantable volume because it appeared to be more closely related to the annual growth. For example, many plots which had been cut over heavily had no merchantable volume, yet they grew at totally different rates because of and in proportion to the basal area that remained.

Re-creation of the residual stand and its original basal area was accomplished in much the same manner that the stand had been reconstructed at 10-year intervals after cutting, viz., by subtraction of diameter growth and addition of mortality losses. These values, when finally secured, proved to be very irregular and had to be brought to even intervals of 10 square feet by interpolation.

A graphic method [1] relating the dependent variable to two inde-

[1] Bruce, Donald, and Schumacker, F. X., *Forest Mensuration*. New York: McGraw-Hill Book Co., 1935.

pendent variables, neither of which is related to the other, was then chosen. It involved the preparation of a curve for the dependent variable (volume) over one of the independent variables (years after cutting) and then investigating the relation between the residuals from this curve and the other independent variable (residual basal area). In the end two sets of curves were drawn on each graph, one for spruce and balsam fir and the other for all species. Figures 1, 2, and 3 (pp. 124–126) show these graphic relationships, and Table I (pp. 128–129) gives the values taken from them.

DISCUSSION

Wide variation in the origin of each set of curves seems odd, but in view of the cutting practices employed in this region is not altogether surprising. These practices allow little or no merchantable volume of spruce and fir to remain after cutting, but frequently permit large amounts of the other species to do so. The pitch of the curves shows the rapidity of growth of each group. It is significant that the volume of spruce and fir exceeds that of all species combined by about 1.4 times in all types except the white spruce–balsam fir–paper birch; here it is about even. It is even only because considerable quantities of aspen make up for the slow growing tendencies of the other nonpulping species.

This comparison of growth rates might be misconstrued. It does not mean that the spruce and fir in a certain stand would grow 1.4 times as fast as all the trees in the stand, but simply that a stand of spruce and fir would grow faster than one of mixed species, including spruce and fir, if equal amounts of basal area were present.

Conformity of the curves to the original data may be judged by the size of the aggregate difference. Should the difference work out to within one per cent, as it does in each of these cases, the curves are said to fit the data acceptably.

Wide variation in volume between the three types indicates that there is considerable variation in site quality. On this account it is probable, but by no means certain, that there is little variation of site quality within each type. The inference might be checked by studying the variation of each plot from the curved average representing that condition. Ordinarily the more a plot is pulled away from the average the more it is affected by site factors and the larger will be the average deviation and variation of site quality within each type.

TABLE I

GROWTH IN MERCHANTABLE VOLUME ON CUTOVER SPRUCE–FIR PULPWOOD LANDS IN NORTHERN MICHIGAN

BLACK SPRUCE TYPE

Residual basal area† in sq. ft.	Number of years after cutting									
	10		20		30		40		50	
	Volume in cords *									
	Spr.–fir	All species	Spr.–fir	All species	Spr.–fir	All species	Spr.–fir	All species	Spr.–fir	All species
10	1.2	1.0	2.6	2.2	4.1	3.2	5.4	4.3	6.8	5.5
20	2.6	2.2	5.4	4.0	8.0	5.8	10.2	7.6	12.1	9.4
30	3.9	3.6	8.1	6.1	12.1	8.6	15.1	11.2	18.3	13.6
40	5.2	5.3	10.9	8.6	16.0	12.0	20.6	15.3	24.5	18.5
50	6.6	7.3	13.7	11.5	20.2	15.7	25.9	19.9	30.8	24.1
60	8.0	9.6	16.5	15.0	24.7	20.3	31.3	25.6	37.0	30.9
70	..	12.2	..	18.6	..	24.9	..	..	..	..
80	..	14.8	..	21.7	..	28.3	..	..	..	..

Aggregate difference, + .002 % (spruce–fir curves) + .70 % (all species)
Average deviation, 48 % (spruce–fir curves) 46.2 % (all species)
Basic number of plots, 68

WHITE SPRUCE–BALSAM FIR–PAPER BIRCH TYPE

Residual basal area† in sq. ft.	Number of years after cutting									
	10		20		30		40		50	
	Volume in cords *									
	Spr.–fir	All species	Spr.–fir	All species	Spr.–fir	All species	Spr.–fir	All species	Spr.–fir	All species
10	2.1	2.1	4.6	4.1	7.2	6.0	9.6	8.0	11.8	10.0
20	3.9	4.6	8.1	8.0	11.9	11.4	15.3	14.8	18.4	18.2
30	5.8	7.1	11.4	12.0	16.6	16.8	21.2	21.5	25.4	26.3
40	7.6	9.6	15.0	15.8	21.5	21.9	27.3	28.0	32.7	34.1
50	9.5	12.0	18.1	18.5	25.2	24.9	31.0	31.4	36.5	37.7
60	11.4	13.6	20.6	20.2	28.3	26.7	34.1	33.2	..	39.7
70	..	15.0	..	21.6	..	28.4	..	35.0	..	..
80	..	16.2	..	23.1	..	30.0	..	37.0	..	..
90	..	17.5	..	24.6	..	31.6	..	..	..	..
100	..	18.8	..	26.6	..	33.0	..	..	..	..

Aggregate difference, + .23 % (spruce–fir curves) + .14 % (all species)
Average deviation, 33 % (spruce–fir curves) 25 % (all species)
Basic number of plots, 68

* 85 cubic feet to one standard cord.

† For equivalent basal areas spruce and fir alone will generally produce more volume at a definite date after logging than will all species combined.

TABLE I (*Concluded*)

NORTHERN WHITE CEDAR TYPE

Residual basal area † in sq. ft.	Number of years after cutting									
	10		20		30		40		50	
	Volume in cords *									
	Spr.–fir	All species	Spr.–fir	All species	Spr.–fir	All species	Spr.–fir	All species	Spr.–fir	All species
10	2.0	1.4	4.4	3.8	5.6	6.1	6.0	8.5	6.7	11.0
20	3.4	2.8	6.8	6.5	9.2	9.9	9.9	13.4	11.5	16.7
30	4.9	4.8	9.3	9.2	12.8	13.6	14.1	18.0	16.9	22.4
40	6.3	6.8	12.0	12.0	16.3	17.0	18.2	22.1	22.4	26.2
50	7.8	8.8	14.3	14.2	20.0	19.7	22.2	25.3	27.4	30.4
60	9.1	10.8	16.8	16.2	23.6	21.6	29.0	27.0	34.0	32.5
70	..	12.9	..	18.0	..	23.1	..	28.2	..	33.4
80	..	15.0	..	19.8	..	24.6	..	29.4	..	34.1
90	..	16.7	..	21.3	..	25.7	..	30.2	..	..
100	..	18.5	..	22.5	..	26.8	..	..	..	..

Aggregate difference, + .95 % (spruce–fir curves) — 1.09 % (all species)
Average deviation, 18 % (spruce–fir curves) 19.3 % (all species)
Basic number of plots, 37

* 85 cubic feet to one standard cord.
† For equivalent basal areas spruce and fir alone will generally produce more volume at a definite date after logging than will all species combined.

Unfortunately, all the average deviations are large, particularly for the black spruce type, and hence it would appear that there are great variations of site quality within each type and a need for breaking the plots up into several groups, so that averages can be obtained for each. It is the opinion of the writer that the wide deviation of plot volumes is due not so much to wide variation in site qualities within each type as to differences in stand structure. Differences in stand structure will cause a stand of, let us say, 20 or 30 square feet of basal area per acre to have no merchantable volume or a rather large amount, depending on the size of the individual trees. Under these circumstances there would be large deviations from the average, even though the site remained the same.

The black spruce type is usually found on very acid wet organic soils. Under these conditions growth in volume is very slow, averaging only about 0.20 cord per acre a year. Whatever growth does occur, however, is generally valuable for pulpwood, because of the heavy representation of black spruce. The white spruce–balsam

fir–paper birch type commonly occurs on better-drained although, perhaps, heavy soils. Here volume growth is almost three times as fast as on the average black spruce site and amounts to 0.55 cord; of this, probably not more than 50 per cent is spruce and fir. The northern white cedar type, with which some of the pulping species are found, occurs principally on the sweeter swampy soils typical of limestone regions. Since it occupies middle ground with respect to moisture and acidity its growth rate, 0.45 cord, is not out of line.

APPLICATION OF GROWTH TABLE

The most important use of the table is in predicting future volumes and volume growth on cutover areas. For this a field survey is essential in which all living trees down to and including the one-inch class should be tallied on a representative portion of the area and the total basal area computed. The type and area of the tract are also needed. If volumetric information for spruce and fir alone is desired, only these species need be tallied. For example, suppose a field survey on a black spruce cutover area disclosed 18 square feet of residual basal area per acre, of which 12 square feet is in spruce and fir. An estimate of volume 20 years hence is required. By interpolation from the first section of Table I a volume of 3.16 cords of spruce and fir and 3.64 cords of all species is secured. The table or charts can also be used to tell how many years must elapse before a volume sufficient to attract an operator can be obtained.

STAND COMPOSITION

The character of the stand after logging depends, for the most part, on the severity of the cutting and the former forest type. Stands that have been heavily cut over retrogress, that is, decline to a worse state. According to statistics released by the Forest Survey operating in the Lakes States, from 20 to 25 per cent of our original spruce–fir pulpwood area has been denuded by heavy cutting and fire. Those that have not been have suffered great losses in density and representation of the two main pulping species. On the other hand, it is evident from the plot data in this study that spruce and fir areas that have been cut over lightly or moderately are much more apt to maintain themselves against the intrusion of less valuable species and to grow at a faster rate.

Heavily cutover black spruce types are somewhat more liable to

become denuded than either of the others, chiefly because few species exist to take the place of the spruce. Difficulty in reclaiming a site from aggressive water-loving vegetation is another factor of importance. Areas that are not actually denuded, however, seem more inclined to return to spruce than to any other species. On only about 30 per cent of the plots did the composition change sufficiently to enable one to say that the type had really changed. Lack of competition from other tree species probably accounts for this "better than expected" showing. Those that did change turned principally to cedar and tamarack.

Cutover white spruce–balsam fir–paper birch types are less stable. They do not become denuded through cutting as easily as black spruce, because other species are always ready to take the place of the spruce and balsam fir that are removed, but they do burn over more frequently. Cutover areas that also burn over return to aspen almost without exception. Even in case the areas are not burned, aspen usually gains a strong foothold. Forty per cent or more of the plots measured showed aspen or some other aggressive hardwood taking over the site. On the wetter sites formerly occupied by this type white cedar furnishes the chief opposition to the return of spruce and fir. It definitely gained possession of about 20 per cent of the plots. From this condition there seems to be slight chance of early recovery, for, in view of the data gathered in the northern white cedar type, almost no kind or degree of cutting seems to favor spruce and fir.

GROWTH OF INDIVIDUAL SPECIES

Growth rates of individual species are valuable in determining silvicultural preferences and treatments. Figure 4 (p. 132) shows the D.B.H. growth of all the important species on spruce–fir cutover areas in northern Michigan. The curves originate from zero merely for purposes of comparison; actually all size classes were averaged to secure them. It is interesting to note that white spruce, a species widely recommended for planting, outgrows aspen over the course of forty years, despite the fact that several years are required to enlarge its crown before it can take full advantage of any release that may be provided, whereas the aspen gets an immediate start. Balsam fir likewise grows rapidly and, as shown by Figure 5 (p. 132), responds well when released from suppression. Hemlock, perhaps the third best pulping species after spruce and fir (although a wide gap sepa-

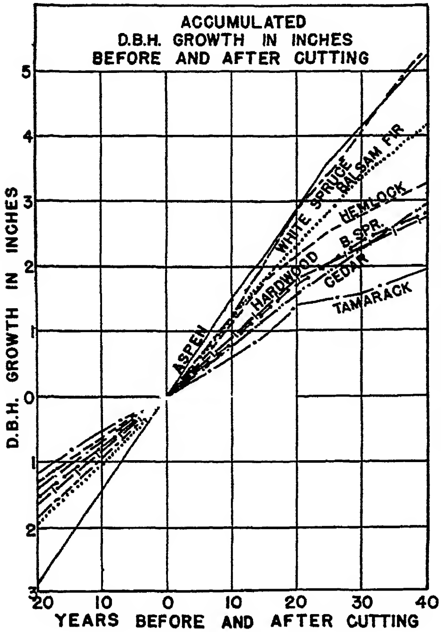


Fig. 4

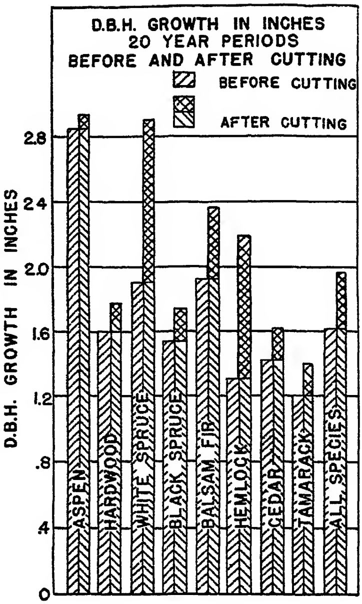


Fig. 5

rates them), also recovers very well from suppression, but seems incapable of maintaining the fast pace beyond fifteen years. Virtually all the other species exhibit small increases in diameter growth (see

TABLE II

Growth in Inches at D.B.H. in Twenty Years

Species	Growth before cutting	Growth after cutting	Response to release
White spruce	1.89	2.89	1.00
Black spruce	1.53	1.73	0.20
Balsam fir	1.93	2.38	0.45
Hemlock	1.30	2.19	0.89
Cedar	1.42	1.61	0.19
Tamarack	1.17	1.40	0.23
Aspen	2.84	2.93	0.09
Mixed hardwoods	1.60	1.76	0.16

Table II, p. 132), but they too soon revert to their normally slow pace. Since these growth rates are average for all site conditions and since the averages are strongly influenced by the preponderance of information acquired where the species is found most consistently, too much dependence should not be placed in them when one species is compared with another on the same site. Black spruce, for example, has sometimes shown the ability to keep up with balsam fir and white spruce when it occurs on good sites, but because it is usually found on poor sites its average is low. Before growth rates for each site quality can be determined, further work will be necessary.

SUMMARY

1. The most important factors affecting the volumes on cutover areas are residual basal area at the time of cutting, elapsed time after cutting, and site quality, which in this study was assumed to coincide with the former forest type.

2. Charts and tables have been prepared from the collected data to predict future volumes of cutover areas. A field survey to determine type, acreage, and residual basal area is a necessary preliminary.

3. Growth in merchantable volume averages for the black spruce type, 0.20 cord per acre per year; for the northern white cedar type, 0.45 cord; and for the white spruce–balsam fir–paper birch type, 0.55 cord.

4. Growth rates of spruce and fir compare favorably with those of associated species and show that, if these species are given a fair chance, they will maintain themselves against all opposition.

5. Heavy cutting is more inclined to cause changes in composition in the white spruce–balsam fir–paper birch type than in the black spruce type, although it is not so apt to denude the site.

6. Recovery of our cutover spruce–fir pulpwood lands depends on (*a*) the nucleus of spruce and fir left after logging, (*b*) the rates of growth of these and associated species, (*c*) the dominance of inferior species left after logging, and (*d*) the tendency of shrubs to monopolize the site.

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THE USE OF LOG GRADES IN APPRAISING LUMBER VALUES OF SELECTIVELY CUT NORTHERN HARDWOOD TIMBER

WILLARD S. BROMLEY

THE use of log grades as a means of determining the relative quality of logs and trees was introduced into the region of the Great Lakes by the Lake States Forest Experiment Station at St. Paul, Minnesota, through its Forest Survey. The Survey log grades have also been employed as a device in appraising the value of selectively cut stands of hardwood timber. It is the purpose of this paper to describe and discuss the significance of a check on the use of these grades in appraisal work in northern hardwood forests. This objective is reached by:

1. Describing how the value of the lumber in six sets of logs was estimated by means of log grades.
2. Comparing these appraised values with the values calculated from tally of the lumber by lumber grades actually sawed from the same sets of logs in respect to: (*a*) the percentage of total lumber value removed by each of the six sets of logs by species; (*b*) the average value per thousand board feet of lumber from each group of logs by species.
3. Discussing the applicability of log grades to standing trees and selectively cut stands.

The field work was conducted on a tract of timber which was marked selectively with five different objectives and then clear-cut. Every log was graded and scaled. This field record formed the basis of six combinations (including clear-cutting) of logs in the same stand. Lumber values were appraised, and the results compared favorably with the values calculated from the lumber tally and grading of every board cut from the logs. Log grading produced more accurate appraisals of the values of different portions of the forest stand studied than could be made without grading.

I. THE APPLICATION OF THE LOG GRADES

Historical Background

In 1937 Henry G. White read before the Forestry Section of the Michigan Academy a paper [1] in which he pointed out that no accurate method of determining the value of selectively or partially cut hardwood stands in this region was available. He illustrated the difficulty of arriving at reasonable stumpage or lumber values for various forms of selective cutting in which the quality of the trees ranges from the best to the poorest. The log-grading system of the Forest Survey was suggested as a solution to the problem of measuring timber quality.

A subsequent logging and milling study conducted at Phelps, Wisconsin, by various branches of the United States Forest Service, proved that there were marked differences in values between the respective log grades. To determine whether the information furnished by the Phelps study would enable a forester to appraise to a reasonable degree of accuracy the value of lumber removed in partial cutting it would be necessary to grade a specific cut of logs and then check the value obtained by grading and appraising all the lumber cut from them. An opportunity to make such a check was presented by a marking and mill-scale study conducted by the Forest Service at Alberta, Michigan, on lands of the Ford Motor Company.

Field Work

On a 30.6-acre tract of northern hardwood timber west of Alberta two principles of marking selectively were tried, with two entirely different objectives:

1. The purpose of one method, referred to as "economic selection" because trees of the highest quality and greatest financial value are marked and cut first, is to produce the greatest net returns per thousand board feet or per acre *now.*

2. The goal of the other, called "silvicultural selection" since it requires the removal of the trees which are contributing the least to the general welfare and growth of the stand, is to obtain *in the*

[1] "An Introduction to the Study of Timber Quality in Lake States Hardwoods," *Pap. Mich. Acad. Sci., Arts, and Letters,* 23 (1937): 339–348. 1938.

future the maximum net growth of forest products of the most valuable species adapted to the site.

With each objective three degrees of cutting were marked in the woods. All the living trees 11.0 inches in diameter and larger at breast height were designated for removal by recording the tree number in one of three categories, "cut," "leave," or "cull." After all the methods of marking had been completed on the same area, all the merchantable trees were felled. The tree number and the position of the log in the tree were recorded on each log. Then the logs were scaled and graded in the woods. An effort was made to disregard the condition of the ends of the logs during the grading, with the object of keeping the grading comparable in difficulty to the grading of the same logs in standing trees. The gross scale, net scale, grade, and other information about each log were all taken by the man who performed this part of the work.

The grades used at Alberta were based on those applied by the Forest Survey in the Lake States, as described by White in his article. It seemed necessary to depart from these grades in two details: (1) The use of an estimate of the percentage of No. 1 Common and better grades of lumber in the log was omitted entirely. (2) A set of equivalent values to convert various log defects to the "standard defect" of the Survey grades was added. These equivalents and other specifications of the grades used at Alberta are shown in Table I (p. 138).

After the logs had been scaled and graded in the woods they were hauled to the sawmill at Alberta, where each board sawed was numbered and graded by a licensed inspector of hardwood lumber. When the mill-scale study was completed the Forest Products Laboratory had a complete record of the number of board feet, by lumber grades, that were sawed from every log and tree in the tract. This information enabled the Laboratory to calculate the value of the lumber marked for cutting by each of the methods indicated in the woods. The preliminary results of this work were completed in the spring of 1939.

Appraisal of Lumber Values

Before these results were obtained the author had arrived at the lumber values by using the information developed for logs by grades in the study at Phelps, Wisconsin. This was done by:

1. Summarizing the net-scale volumes of logs by species, by log grades, and by the diameters of the small ends.

2. Converting the net-scale volumes to lumber tally by the use of overrun factors obtained in the Phelps study.

3. Multiplying the percentage of each lumber grade produced in the Phelps study by the current price per thousand board feet being paid for the lumber of different grades. This gave the average prices of the lumber cut from logs of specific sizes and grades.

4. Multiplying the average prices derived in item 3 for each of the sizes within a grade by the volumes obtained in item 2. The result gave the appraised value of the lumber which it was estimated would be cut from the logs selected by each method of marking.

TABLE I

LOG GRADES USED IN THE ALBERTA MILL-SCALE STUDY

Grade	D.I.B. in inches	Length in feet	Standard defects *		Soundness percentage (based on regular scaling procedure)
			Defect	Equiv. diam. 1–3″ knots	
No. 1	12–14	12–16	1	3″	90
	15–17	12–16	2	6″	85
	18 up	12–16	3	9″	80
No. 2	10 †	10	1	3″	85
	10–11	12–16	2	6″	80
	12–14	12–16	3	9″	75
	15 up	12–16	4	12″	65
No. 3	10 †	10	No limitation set		50

* *Standard defects:* One knot 3 inches or more in diameter; or two knots 1 to 3 inches; or three knots ⅝ to 1 inch. If a defect is similar to knots in its effect on lumber, conversion is made on the basis outlined.

Sweep and crook: Allowance is made by cutting down scale. Bad cracks and seams may be counted as defects and also scaled out.

Cracks, seams, or folds:

	STANDARD DEFECTS			
	1 face	*2 faces*	*3 faces*	*4 faces*
Full log length........	1	2	3	4
One-half log length....	½	1	1½	2

† The minimum top D.I.B. and the minimum length of log vary with the standard of utilization practiced. The Forest Survey used 8 inches as a minimum top and 8 feet as a minimum length.

To follow this procedure every time an important change in lumber prices takes place would involve a tremendous amount of computing, one of the limitations of using log grades. Only the larger tracts of timber can be appraised in this manner if the cost of appraisal is to be kept within reasonable and practical limits.

II. COMPARISON OF RESULTS

When the appraised values obtained by applying the grades to the logs in the woods are compared with the values obtained by lumber grading at the mill, two significant questions are raised: (1) Did the log grades enable the appraiser to learn the relative value of different portions of the stand as marked? (2) Were the average values per thousand board feet of lumber derived from use of log grades within a reasonable degree of similarity to those obtained from the lumber tally?

In trying to answer the first question the author has reduced the total dry-lumber values to a percentage comparison, as shown in Table II:

TABLE II

COMPARISON OF THE PERCENTAGE OF VALUE REMOVED

Type of cut	Percentage of volume cut	Percentage of dry-lumber value cut					
		Sugar maple		Yellow birch		Elm	
		Log grades	Lumber tally	Log grades	Lumber tally	Log grades	Lumber tally
Clear-cut	100	100	100	100	100	100	100
Heavy economic	39	55	53	60	59	11	10
Light economic	29	42	42	46	44	9	9
Heavy silvicultural	79	77	75	68	67	96	95
Moderate silvicultural	54	46	44	53	51	65	65
Light silvicultural	20	16	14	22	23	20	20

In every method the log grades enable the writer to learn the relative proportion of total lumber value removed from the stand within 2 per cent of the value determined for the entire stand. This does demonstrate that the use of log grades will enable an appraiser to evaluate various cuts or portions of the same stand selected with a variety of objectives.

The second question relates to the practicability of an appraiser using log grades to determine the average lumber value of the various species in the stand within a satisfactory degree of accuracy. The results are given in Table III.

TABLE III

COMPARISON OF AVERAGE LUMBER VALUES

(On the basis of price scale used in Phelps study)

	Average value per M		
	Sugar maple	Yellow birch	Elm
A. Value per M appraised by use of log grades..........	$31.00	$33.90	$31.62
B. Value per M based on lumber tally of Forest Products Laboratory..........	26.97	33.44	32.33
Difference.................	+ $ 4.03	+ $ .46	− $ .71
Difference in percentage....	+ 14.9	+ 1.4	− 2.2

The results for yellow birch and elm are within a reasonable range of accuracy, but the value of sugar maple in the stand was overestimated. Since the proportion of large and high-grade sugar maple logs was as great as or greater than that given in the mill-scale study made at Phelps, the author is of the opinion that the discrepancy is due primarily to the presence of mineral stain in trees on the Alberta tract.

III. APPLICABILITY OF LOG GRADES TO STANDING TREES

This study has shown that the application of grades to logs before cutting gave reliable appraisals of lumber value, except for sugar maple. Since the grading was done under the assumption that the log was being graded in the standing tree, it might be concluded that satisfactory results would be obtained in applying the grades directly to standing trees. Such a conclusion is not entirely safe in view of the results of an attempt to do this in another phase of the mill-scale study at Alberta. It was found that most of the men, including the author, had a tendency to grade too high because of the extreme long-butting practices of the cutters and the difficulty of estimating where and how long the logs were to be cut.

As a final check on the usefulness of the Forest Survey log grades the appraised values were calculated without employing any grades. These results are based on average values per thousand board feet of lumber from trees in the Phelps study. A comparison of values obtained is shown in Table IV.

TABLE IV

APPRAISED VALUES WITH AND WITHOUT GRADES

Species	Average value per thousand board feet		
	Appraised values		Actual value from lumber tally
	Without log grades	With log grades	
Sugar maple	$29.90	$31.00	$26.97
Yellow birch	34.60	33.90	31.62
Elm	31.40	31.62	32.33

The results obtained without grades are so close to those secured with grades that it does not seem worth while to apply them to the entire stand. In a comparison of the value of a portion of the stand with that of the entire stand, however, the log grades did produce results which were more accurate than those obtained when no grades were used. This is shown for the sugar maple trees by comparing the value per thousand board feet of the total stand with the values per thousand appraised for each of the five combinations of logs marked for selective cutting at Alberta (see Table V, p. 142).

In all five cuts the grading of logs permitted a closer estimate of the values of the trees removed than that obtained when grades were not used. This leads to the conclusion that log grades should be applied, but only to the trees removed or to the trees left. It should not be necessary to apply them to both portions of the stand unless the entire stand varies materially from the average in respect to the distribution of trees by species, size, and quality. The value of one portion valued with log grades subtracted from the value of the total stand appraised without grades gives the value of the remainder of the stand.

Although the results afford little information regarding the application of log grades to standing trees, the trends shown for logs may

TABLE V

AMOUNT BY WHICH AVERAGE VALUE OF SELECTIVE CUTS EXCEEDED AVERAGE VALUE OF TREES CLEAR-CUT

Type of cut (Sugar maple only)	Difference per thousand board feet		
	Appraised values		Actual value from lumber tally
	Without log grades	With log grades	
Economic selection:			
Heavy cut (39 %)....	$1.80	$4.30	$3.48
Light cut (29 %).....	3.10	4.98	4.39
Silvicultural selection:			
Heavy cut (79 %)....	2.30	1.90	2.01
Medium cut (54 %)..	1.50	.90	.44
Light cut (20 %).....	1.50	− .40	− 2.10

well be considered seriously. It is likely, then, that appraisals of trees to be cut will tend to overestimate values under silvicultural selection and to underestimate them under economic selection. If governmental agencies such as the United States Forest Service attempt to purchase the residual timber on private land which is to be selectively cut, the value of the trees marked for cutting will probably be appraised too high and that of the residual stand too low unless a measure of the difference in quality is obtained by use of log grades, tree grades, or other devices.

UNIVERSITY OF MICHIGAN

NATIONAL-FOREST LAND MANAGEMENT IN MICHIGAN

H. BASIL WALES

THE national-forest system is comparatively young, yet it constitutes one of the oldest continuous attempts at federal land management in the United States. It is true, of course, that other reservations have been made, but they have been almost entirely for "occupancy" use rather than for the management of the soil as a productive resource. The present paper deals with this latter aspect of federal control as it is manifested in the national forests of Michigan. It is not argued here that "occupancy" of land for specific purposes may not be good land management. In fact, good land-management practices must necessarily include withdrawal of certain areas of soil for higher uses than the production of crops.

The basic creative act, that of March 3, 1891, simply authorized the president "to set apart and reserve, in any state or territory having public lands bearing forests, in any part of the public land, wholly or in part covered with timber or undergrowth, whether of commercial value or not," certain areas as public reservations. The areas so set aside by presidential proclamation as forest reserves were just what the name signifies, "reservations," with but little authorization for administration and constructive land management. They were handled very largely on a custodial basis. By the Act of February 1, 1905, Congress transferred the administration of the forest reserves from the Secretary of the Interior to the Secretary of Agriculture. The name was changed from "forest reserves" to "national forests" to emphasize a new conception, that the forests were not "bottled up," but were for use by the people of the United States.

In his letter of February 1, 1905, to Gifford Pinchot, then head of the Forest Service, James Wilson, the Secretary of Agriculture, enjoined that the national forests be so administered as to result in "the greatest good to the greatest number in the long run." He also stated: "You will see to it that the wood, water and forage are pre-

served, and wisely used for the benefit of the home builder, first of all, upon whom depends the best and permanent use of land and resources alike. The continued prosperity of the agricultural and livestock interests is dependent upon a permanent accessible supply of wood, water and forage, as well as upon present and future use of these resources, under business-like regulations enforced with promptness, effectiveness and common sense."

Secretary Wilson recognized that the national-forest areas were more than just timber-producing areas. In the western states water was one of the most vital resources, and watershed values were not to be impaired. Forage also was an important asset. The use of forage was one of the items which influenced the change from "forest reserves," to be held for timber production and watershed protection, to "national forests," all the resources of which were to be open to use by the public under proper regulation. The forage crop was a resource, to be harvested by livestock and transmuted into meat and wool. It was likewise serviceable in holding soil in place, and was to be used wisely. Although he did not specifically include other resources in his letter to Mr. Pinchot, the implication was there. The national-forest areas embraced land suitable for agriculture or rich in minerals, and laws were passed whereby such land could be entered and developed by private enterprise. The importance of portions of the national forest for occupancy for uses which were legitimate and of value in community development or to an individual was apparent. Summer-home use was provided for. In other words, there was early recognition that the national forests not only were for timber production on a continuous basis and for stream-flow regulation, but might also be utilized, at the same time, for many and varied purposes without detriment to the primary one for which they were reserved. Secretary Wilson instructed that they be managed for "the greatest good to the greatest number in the long run."

To this varied use of the forest the term "multiple use" has been given in recent years. To some extent the term is a misnomer, for it does not mean that every acre of national-forest land should be used in a multiplicity of ways; it should be applied to the land area as a whole. "Multiple use" refers to the utilization of all of the land-resource values — as opposed to single-purpose management. Some portions of a national forest may be employed for several purposes

at one and the same time without serious detriment to the primary one. On many forests grazing is compatible with timber production. On others, particularly the hardwood ones of the East, it is incompatible, at least in any degree of intensity. Timber can be grown and harvested, and at the same time the forest can be the home of game and other forms of wildlife. Silvicultural methods may have to be modified somewhat in favor of special requirements of wildlife, but as a matter of fact the harvesting of timber on a progressive basis improves conditions for many of the game species which inhabit the forest.

Harvesting the timber crop, especially on a partial or a selective cutting basis, is not necessarily incompatible with the recreational use of the forest. With the cutting of low stumps, and careful attention to utilization and slash disposal, the average recreation seeker will hardly miss the few trees taken out of the stands. On certain areas, such as those along streams, on lake fronts, and in roadside zones, recreational use and the necessity of maintaining aesthetic values may require the giving of the area a dominant classification for that purpose, and the subordinating of timber production and forage utilization. But even here the trees must be kept in a thrifty growing condition. When a tree has served its purpose in a stand good conservation demands that it be cut and utilized. Provision must be made for the gradual replacement of veterans with younger, thrifty trees, but it must be done in such a way, if at all possible, as not to leave unsightly scars. The transition should be undiscernible except to the most discriminating eye.

There may be areas which should be managed for some major purpose other than timber production or recreation. Watershed protection must inevitably be a dominant classification wherever soil, slope, or special condition is such as to require it. The necessity of preventing destructive erosion, either by wind or water, is paramount in connection with each and every use of the forest.

Although the Secretary particularly emphasized assistance to the home builder, still it must be remembered that the national forests are the property of the entire nation. Hence they must serve the general public as well as the individual settler or home builder who may live within or near them. Their interests must be carefully correlated. Land-use planning is a prerequisite to land management. Planning the use of a small tract in private ownership may be a

relatively simple matter or it may be somewhat complicated. A level tract of rich, fertile soil may at once be definitely planned for permanent agricultural use and, so far as an individual owner is concerned, may be managed on this basis. But if the land is within a valuable reservoir area, it may have a higher value for water power or flood protection. Again, an owner may decide that it can be used for agriculture and at the same time produce a valuable crop of upland game birds or small game animals. It may be so located as to have a higher value for recreation purposes, perhaps a golf course. If it should be somewhat steep or rolling, then the best use may be a combination of agriculture, permanent pasture, and forest.

If the determination of the best use of a small area is difficult, then obviously the planning of proper land use on a national-forest area of approximately a million acres will require detailed study. Particularly is this true when one considers the many and varied interests of the owners of the national forests. One hundred and thirty million people have a general interest in the cash returns and the benefits which can be secured on a broad public basis. A few million people in an individual state, and a still smaller number in a county or a community, have a more direct interest. Finally, the settlers within or near a forest are greatly concerned, for their use of the forest resources may result in a supplemental income sufficient to make possible a reasonable American standard of living.

The national forests were at first very largely in the West. The forested land in the East had practically all passed to private ownership, and had been more or less destructively logged. The only areas of public domain in the East of sufficient size to warrant reserving as national forests were in Florida, Arkansas, Minnesota, and Michigan. Here in the north-central region a portion of the present Superior National Forest in Minnesota and some relatively small areas in what is now the Huron and the Marquette National Forests in Michigan were set aside from the public domain. The Weeks Law, passed by Congress in 1911, authorized the purchase of land by the federal government on the headwaters of streams. An amendment to this law, passed in 1922, authorized the purchase of land for timber production, as well as for watershed protection.

After the Michigan State Legislature had passed an enabling act five national-forest purchase units were set up. They have since been proclaimed national forests. The gross area within the national-forest

boundaries in Michigan amounts to 5,095,121 acres. It is estimated that approximately 785,000 acres will be nonpurchasable, and will, therefore, remain in private ownership. The ultimate area which it is expected will be acquired for national forests is 4,310,000 acres. One million eight hundred and eighty-one thousand acres have already been purchased or are well along in the process of title transfer. The purchasing is, therefore, 43.6 per cent complete.

As before indicated, these areas are now under management as national forests. There are, however, only four administrative units; the Hiawatha and the Marquette National Forests have been combined for administration under one forest supervisor.

The establishment of a national forest or of a national-forest purchase unit is one phase of land-use classification. The basic creative act of 1891 and the Weeks Law, as amended, both require that the land be "chiefly valuable for timber production or watershed protection." An examination of the areas to determine general adherence to this is a prerequisite to establishment. Boundary lines are drawn to include major areas of forest soil and to exclude areas primarily valuable for other purposes, and at the same time to define logical administrative units.

The Manistee National Forest, for example, stands on two legs, astride an area of good soil around Fremont and Newaygo, which, with proper adjustment of farm practice, will probably be suitable for permanent agricultural use. The west line of the forest follows closely the east side of a highly valuable fruit and resort country. The east boundary marks the approximate line between forest soil and soil just a little better which has been partially developed for agriculture. There was no definite reason for stopping on the north end except that there are some farms in the Mesick and Kaleva territory and that it is only a relatively short distance to the Fife Lake State Forest. It should be mentioned that the east line originally included most of what is now the Baldwin State Game Refuge; but when the State Conservation Department signified its desire to give that area a high value for wildlife purposes, the national-forest line was pushed back to the west.

An examination of any one of the five national-forest areas in the state will show that by and large the boundaries are logical and that the national-forest area includes, in major portion, land which is "chiefly valuable for timber production and watershed protection."

With the possible exception of the west end of the Ottawa, the national-forest areas were real problem areas, areas "out of production," which should be restored and rehabilitated in order that they might become an asset rather than remain a liability. The western portion of the Ottawa was included in the national-forest purchase unit in the hope that some arrangement might be made whereby the large acreage of virgin timber would remain fully productive and not be devastated by a continuation of destructive logging practice.

The purchase of nearly 50 per cent of the area set up for acquisition does not finish the task of use classification. The Forest Service recognizes that forest land management is not just timber production and watershed protection. There are many other values inherent in a forest area to be protected and enhanced. All the resources are to be used and enjoyed.

In any area of a million acres it is inevitable that considerable good soil will be included within the exterior boundaries — good soil for the growth of exceptionally fine timber, but likewise valuable for the production of agricultural crops. The federal government does not desire to purchase such areas of good farm soil, except as they may be small and more or less isolated. The cost to local government of constructing and maintaining roads and keeping them open during the winter, and of furnishing school facilities to settlers on such tracts, justifies retirement from agricultural use.

Thirty-five years ago the Secretary of Agriculture instructed that the forest be managed for the home builder first of all. This is still one of the primary objectives of national-forest land management. Areas of good soil are set up for community development. Where land is acquired within such an agricultural community, it is used either for exchange or under special-use permits for agriculture or for pasture, so that the agricultural community is strengthened. An endeavor is made to have each farm unit within such an area self-supporting. The farmer may need additional cropland, but it has been found that he is mostly in need of summer pasture. Suitable pasture areas are provided to the fullest possible extent.

The forests of Michigan are accessible to areas supporting a large industrial population. They are within two or three days' drive for one quarter of the people of the United States. Obviously, these areas have a very high recreational value. Trees and water are basic requirements for this use. The regular timber-production practices

provide timber and help to protect water. If forest areas are to serve the highest public recreational value, access to water is important, and the acquisition program definitely contemplates the purchase of some lake and stream frontage. The recreational policy gives use by the general public precedence over the more exclusive semipublic or individual use. Picnic grounds and camp grounds are developed for the convenience of the public, and only after the full needs, so far as they can be foreseen in the future, have been provided for will land be classified for summer homes or resorts. Moreover, there appear to be plenty of summer-home and resort sites available on privately owned land. These areas should remain on the tax roll. The summer visitor is provided for, and areas are also being developed for winter use. Within the five national forests in the state of Michigan fifteen picnic grounds, twenty camp grounds, thirty-six combined picnic and camp grounds, and two winter-sports areas have already been developed.

The wildlife resource on the national forest is given recognition both as a crop to be harvested and in its relation to recreation. Action by the Forest Service is primarily one of the manipulation of environment so as to bring about suitable conditions for the wildlife species. The harvesting of the crop is controlled by the state under state laws and regulations. Winter deeryards which have been purchased are given a dominant classification for that particular use, with timber in a minor status, to be harvested only after the browse becomes unavailable as deer food. The problem of management of deeryards has not yet been solved. Natural regeneration of cedar stands is relatively easy to secure, under a proper degree of protection, but the yards cannot be reproduced if they are used excessively by deer. Not much has yet been done in the matter of game-food planting. However, the Forest Service is going ahead with this in an exploratory way. Areas which are valuable as waterfowl nesting or resting grounds are set aside for this purpose, and water levels are being restored and maintained by the construction of small dams. The entire national forest is considered available as public shooting grounds, except small areas which may be designated by the state for game refuges or sanctuaries. Streams and lakes are being surveyed, and stream improvement work is being done in full coöperation with the State Conservation Department and the Fisheries Institute. In the national forests of Michigan fish are reared in two rearing ponds,

and 19 million fry, 412,000 fingerlings and 18,000 yearlings were planted in 1939 coöperatively.

In the use classification of the land for management purposes special tracts such as wildernesses, natural areas, experimental forests, etc., are designated, and even a wild-flower sanctuary is now under consideration on the Manistee National Forest. In these specific regions timber production is definitely subordinated.

Of course, the primary purpose of the national forest for timber production or watershed protection cannot be overlooked. The Forest Service believes — and, I think, rightly — that timber production, including the harvesting of the crop, can be carried on over most of the national forest area to the benefit of the local people and industry without seriously reducing the highly valuable recreational and wildlife resources. One of the objectives of the Forest Service is to improve the status of the people within or near the forest, and to stabilize communities and industries. The forests are vast reservoirs of work, in the accomplishment of which many people will secure a supplemental cash income, which will mean the difference between poverty and a comfortable living. The harvesting of timber and the fabrication of timber products will provide a part of that income, and as the forest matures the amount of such work will materially increase and thus obviate the necessity of huge relief appropriations.

In the first six months of the present fiscal year 10,503,000 feet BM of timber, having a stumpage value of $21,769.39, were sold from the national forests of Michigan. Figured at the rate of three man days per thousand board feet, this sale of stumpage will provide 31,500 man days of work. It will mean steady labor for over 100 men for a full year, or part-time employment for a three months' period for 400 men. It is admittedly not a large figure, but when one considers the present status of the national-forest timber crop it is indicative of the large employment which will be possible when the national forests are in full production.

The trees which have been sold have served their purpose in the stand. Their cutting will be simply a salvage of wood products, and will in no way deplete the growing stock of the forest. It is simply good conservation to harvest the crop. Recreational and scenic values will not be destroyed and, if what experts tell me is true, wildlife habitat will be improved.

The national-forest units in Michigan are problem areas. They have been cut over and burned over to such an extent that they are no longer fully productive of timber. The Forest Service has been accused of buying the "worst first," yet approximately 75 per cent of the national-forest land is stocked with timber sufficient to give promise of a merchantable crop in the near future. Only about 25 per cent has been devastated to such an extent as to require planting before it will become really productive of timber values. Good land management requires that this nonproductive area become productive. The reëstablishment of a forest growth will result in greatly improved recreational and scenic values. Wildlife experts object to continuous stands of conifer plantations, stating that such areas become "biological deserts." This might be true *if* such plantings were made and *if* an exceptionally good survival of the planted trees were secured. A recent careful analysis of a relatively large area bearing a highly successful twenty-year-old plantation did not support their viewpoint. There were still plenty of openings and edges, and an admixture of species. Moreover, there was game food available, and the area was used by deer and other animals; this wildlife, although not quite so abundant as on adjoining unplanted ground, nevertheless constituted reasonably satisfactory stocking.

In this particular plantation all the overtopping oak was cut out of the stand in 1933 to release the planted trees. This was a mistake, for retention of white oak would have furnished a desirable mast crop as fall and winter food for deer. Sprout growth is replacing the oak which was cut. Part of it should be retained. Opinions differ as to what the future twenty, forty, or even eighty years hence will hold. Will the crowns close up all the openings? I doubt it, even though no intermediate cuttings be made. I anticipate that such cuttings will be made, and that they will admit light for ground vegetation.

This finding of fact is not an argument for the reëstablishment of a forest in large continuous blocks of a single species. Our maps may show as much as 10,000 acres included in a planting area, but I am sure a careful examination on the ground will reveal a variety of types and species, openings and edges, highlands and lowlands, swamp areas and well-drained areas. When the planting job is planned, wildlife requirements are taken into consideration, not on a maximum basis, but on a favorable one. An effort is made to correlate all the interdependent resource values.

A recent publication, *Our Use of the Land,*[1] by Ayres Brinser, with the assistance of Ward Shepard, points to the Forest Service as an outstanding example of single-resource management. This would be true if the national forest were managed only for timber production. National-forest land management aims to capitalize all the resource values inherent in the land within a national forest and to correlate these resources one with the other and on the basis of harvesting the crops without depletion.

Forest Service
United States Department of Agriculture
Milwaukee, Wisconsin

[1] New York: Harper & Bros., 1939.

THE GROWTH AND DEVELOPMENT OF A MIXED-CONIFER PLANTATION

LEIGH J. YOUNG

SUCCESS in forest planting depends in large measure upon a number of fundamental factors, such as proper choice of species, use of the right kind of stock and planting methods, adequate protection of planted area, correct spacing of trees, and, in the case of mixtures, suitable arrangement of species with respect to one another. A good deal of help in arriving at more accurate decisions concerning these factors can be secured from studies of previous planting projects, whether successes or failures. Such a study of one of the oldest forest plantations in Michigan was initiated in August, 1933, under the direction of Professor W. F. Ramsdell of the George Willis Pack Forestry Foundation.

This plantation is a stripwise mixture of five coniferous species that was established in the spring of 1903 upon a 35-acre tract of land owned by the Cleveland Cliffs Iron Company and located about three and one-half miles northeast of the City of Negaunee.

The soil of the area is a light glacial outwash sand, which was covered at the time of planting with a dense growth of grass. That white pine was present in the original forest was indicated by the remains of a number of large stumps of that species. There was no evidence on which to base a determination of the species that were associated with the white pine in the old stand. Prior to planting the tract had been cut over and subsequently burned.

Preparation for planting consisted in plowing rather narrow deep furrows at intervals of about 6 feet to remove the cover of grass. The trees were planted in the furrows, about 6 feet apart. According to the record of the Company, the stock used was as follows:

5,000 Scotch pine, 3 years old
1,000 Scotch pine, 6 years old
12,000 white pine, 3 years old
1,000 red pine, 3 years old
20,000 Norway spruce, 3 years old

This record is incomplete, however, since one strip was planted with Douglas fir, and trees of this species were also mixed irregularly with Norway spruce, white pine, and Scotch pine along the west edge of the plantation.

With one exception the different species were planted in pure strips, running in a north–south direction and varying in width and arrangement. The exception was a strip on which white pine and Norway spruce were mixed. The width of the strips ranged from 5.4 feet to 44.3 feet.

In August, 1933, a permanent sample plot was established in this plantation, one chain in width and extending completely across the area in an east–west direction, so that it crossed all the strips at right angles. At this time all the live trees on the plot were numbered and measured, and a very light thinning was made in the Scotch and red pines. A considerable number of aspen and cherry were cut wherever they were interfering with the growth of the conifers. Thinning was extended to a distance of one-half chain on both sides of the plot to provide isolation. Prior to this time no growth measurements had been made, nor had any cultural operations been performed.

The total area of the plot is 1.875 acres, and the area planted with each of the several species on the plot is as follows:

Norway spruce........	0.9658 acre
White pine...........	0.6246 acre
Scotch pine...........	0.2220 acre
Red pine.............	0.0380 acre
Douglas fir...........	0.0246 acre

Comparative growth figures for the four major species are given in Table I. In computing means it was assumed that the measurable growth for 1933 had been completed, so that the age since planting was taken as 31 years.

In calculating the basal area per acre, the volume per acre, and the mean annual volume growth per acre the areas used were those occupied by each species at the time of planting. As the result of a more rapid early height growth the Scotch and red pines overtopped and suppressed the spruces on adjacent strips and so secured a greater amount of growing space for the trees in the outside rows of each strip than they would have had otherwise. To obtain figures that would represent more accurately the relative productiveness per acre the areas of the strips of Scotch and red pines should include the en-

TABLE I

GROWTH FROM 1903 TO 1933, INCLUSIVE

	Species			
	Norway spruce	White pine	Scotch pine	Red pine
Average diameter breast high in inches..	4.0	5.3	7.8	6.7
Maximum diameter breast high in inches	8.7	10.1	11.8	8.7
Minimum diameter breast high in inches	0.0	1.0	2.5	3.6
Maximum total height in feet.........	35.6	31.7	43.6	41.9
Average total height in feet...........	22.0	19.3	33.7	35.5
Total basal area on plot in square feet..	90.144	62.382	54.966	13.137
Basal area per acre in square feet......	93.336	99.875	247.594	345.71
Total volume in cubic feet............	991.58	421.39	740.94	233.18
Volume per acre in cubic feet.........	1,026.69	674.65	3,337.56	6,136.31
Mean annual diameter growth in inches.	0.129	0.171	0.251	0.216
Mean annual height growth in feet.....	0.71	0.62	1.09	1.14
Mean annual volume growth per acre in cubic feet.......................	33.12	21.76	107.66	197.94

tire growing space of the crowns, and those of the strips of Norway spruce should be limited to the portions on which the spruce has been free from interference by the pines. Revision on this basis would lower the values given for Scotch and red pines and increase those for Norway spruce. Because of the narrowness of most of the strips the effects of the differences in growth of the trees on their edges are considerable.

The few trees remaining on the strip planted with Douglas fir were so badly suppressed and deformed that no measurements of them were taken. On the west edge of the plantation, however, 47 trees that had not been overtopped were measured in 1934 and showed growth as follows:

Maximum height.......	35.0 feet
Minimum height.......	14.0 feet
Average height	23.0 feet
Maximum D.B.H.......	7.3 inches
Minimum D.B.H.......	2.1 inches
Average D.B.H.	4.1 inches

This corresponds closely to the growth made by Norway spruce.

The placing of strips of species of rapid early height growth adjacent to those of much slower growth has resulted in poor natural

pruning on a large percentage of the trees in the stand. The crowns of the Scotch pine are particularly wide, with branches of large diameter, as shown in Plate I. The value of the Scotch pine has been lowered still further by crookedness of bole, a condition that occurs in almost all the trees in varying degrees and is probably due to seed from a poor source. In the white pine height growth has been stunted and normal form destroyed by repeated attacks of the tip weevil. Red pine and Norway spruce have excellent form, except for limbiness. Plate II shows some of the red pine, as it appeared in 1938 after being pruned to a height of 17 feet. The condition of these trees in 1933, before pruning, is illustrated in Plate III.

In August, 1938, all trees on the plot were remeasured and additional thinning was done. The conditions as shown by the measurements are given in Table II.

TABLE II

CONDITION OF STAND IN 1938 BEFORE THINNING

	Species				Plot totals
	Norway spruce	White pine	Scotch pine	Red pine	
Average diameter breast high in inches	4.5	5.9	8.7	7.7	..
Maximum diameter breast high in inches	10.1	10.9	12.9	9.5	..
Minimum diameter breast high in inches	0.0	1.5	4.0	5.5	..
Average total height in feet	24.4	21.2	36.3	43.5	..
Maximum total height in feet	44.3	34.4	48.7	45.7	..
Total basal area in square feet	122.972	69.496	54.674	14.872	262.014
Total volume in cubic feet	1,500.25	736.65	992.33	279.59	3,508.82

The average basal area and the volume per acre for the plot in 1938 were 139.741 square feet and 1,866.03 cubic feet, respectively. This volume represents a mean annual growth of 52 cubic feet per acre for the entire plot since the year of planting.

The growth made by the four principal species during the five-year period between measurements is shown in Table III. Average diameter growth of the Douglas fir for the period 1934 to 1938 was 0.4 inch, and average height increased 6.3 feet.

In 1926 the survival was estimated by one of the cruisers of the

TABLE III

GROWTH FROM 1933 TO 1938

	Species				Plot totals
	Norway spruce	White pine	Scotch pine	Red pine	
Average diameter breast high in inches	0.5	0.6	0.7	0.8	..
Total basal area in square feet	32.828	7.114	6.227	2.338	48.507
Average total height in feet	2.4	1.9	2.6	8.0	..
Total volume in cubic feet	508.67	315.26	251.39	46.41	1,121.73
Average basal area per acre	..	..	..	..	25.861
Average volume per acre	..	..	..	..	598.25

Company at 90 per cent for Scotch pine and Norway spruce, 80 per cent for red pine, and 65 per cent for white pine. The actual stocking of the plot in terms of number of trees per acre in 1933, before any thinning was done, and in 1938, after the thinning of that year, is shown in Table IV.

TABLE IV

STOCKING OF PLOT IN TERMS OF NUMBER OF TREES PER ACRE

Species	*1933*	*1938*
Norway spruce	1,245	1,077
White pine	653	562
Scotch pine	621	549
Red pine	1,262	973

The apparently heavy stocking of the strips of Norway spruce is due to the presence of many small, oppressed trees that are not worth removing in thinning. The abnormally heavy stocking of red pine consists almost entirely of dominant and codominant trees and is possible only because of the unrestricted growing space along the outside edges of the strips. As the trees in the central portion of the spruce strips broaden their crowns this unrestricted growing space will be reduced, better natural pruning of the pine will result, and heavier thinning will become necessary.

A number of important conclusions may be drawn from this study:

1. A stripwise mixture in forest planting is inadvisable unless the species on adjacent strips have very similar rates of height growth on

that particular site. The ill effects of a serious disparity in rates of height growth are greater on narrow strips.

2. This form of mixture has not prevented heavy damage to white pine by the tip weevil.

3. Under present conditions the planting of white pine in stands in this locality will not be profitable.

4. If Scotch pine is to be planted, proper care must be exercised to insure that seed is from a suitable source.

5. The exotic, Norway spruce, has made satisfactory growth on the whole, except on areas dominated by pine, and has been free from any appreciable damage.

6. Red pine has excelled the other species in every respect.

7. The stock and planting method used resulted in adequate stocking, except in the case of white pine.

8. In terms of volume alone, i.e. disregarding quality, the production of wood has been good, since the average for the entire plot during the last five years has been 1.196 cords per acre per year on the basis of 100 cubic feet of wood per standard stacked cord.

University of Michigan

Wide crowns of Scotch pine and suppressed Norway spruce in adjacent rows

Red pine in 1938 after pruning

Red pine in 1933 before pruning. Photograph taken from same point as that shown in Plate II

ZOOLOGY

FACTORS DETERMINING TIME OF BIRTH IN THE GARTER SNAKE *THAMNOPHIS SIRTALIS SIRTALIS* (LINNAEUS) *

FRANK N. BLANCHARD AND FRIEDA COBB BLANCHARD

GARTER snakes (*Thamnophis sirtalis sirtalis*) kept in captivity primarily for the study of inheritance of melanism have proved excellent material for life-history observations. It was realized at the start (in 1922) that the genetical study would require several, or perhaps many, years and the rearing of various broods of young; accordingly, as the snakes were maintained under conditions which, if not quite natural, were at least fairly so, it was thought worth while to keep records on such topics as mating, number and size of young in relation to size and age of parent, time of birth of young, rate of growth, size and age at maturity, length of life, and so on.

When the number of snakes had increased from the original three to several dozen, a study of the factors determining the date of birth of the young was urgently needed because of the inconvenience of its varying from year to year. Usually the young were born in early August (or occasionally in late July), but some years births dragged along annoyingly through the vacation period between the summer session at the University of Michigan and the autumn opening. If the exact length of the period of development could be determined the date of birth could at least be predicted, and it might even be possible to arrange the matings at such a time that observation and care of the broods would not interfere with postsession expeditions. The subject of this paper, therefore, was studied with enthusiasm as soon as data were available.

* Contribution from the Department of Zoölogy, and Paper No. 689 from the Botanical Gardens and Department of Botany, of the University of Michigan.

The authors presented this paper at the meeting of the American Society of Ichthyologists and Herpetologists in May, 1937. The form has been slightly modified for publication, but the matter has not been changed except for the addition of the 1937 results. F. C. B.

LIVING CONDITIONS OF THE SNAKES

The snakes with which these natural-history studies were made were kept at the Botanical Gardens of the University under conditions as natural as was practicable. They lived in a number of pits each five by six feet in area, and about four feet deep, with cement walls and natural ground bottoms. The rims of the pits are about eighteen inches above the outside ground level, and boards cover half of the top of each, for shelter. The fourteen pits adjoin one another in a single row within a grassy court a hundred feet long and enclosed by greenhouses. Here the snakes are free from disturbance. They are healthy and show no restlessness.

The temperatures in the pits are as nearly alike as they could well be under natural conditions. The pits are in a single east–west row paralleling the greenhouses, five feet from the one on the north and fourteen feet from that on the south. The two end pits are not used for the females recorded here, as each of these has a wall backed by the ground instead of by an adjoining pit, which must affect the temperature somewhat. The other twelve are as nearly identical as practicable. The temperature in them is not, of course, the same as that in natural habitats. The pits possibly provide surer winter protection, for in addition to the deep piles of leaves which they contain they are supplied with cold-frame sash. In early spring there is less sun warmth in the pits than in the woods; on the other hand, the wind also is cut off. But, though the conditions are not identical with those in nature, they are uniform throughout the pits, and the setup is the same from year to year.

The snakes doubless forage somewhat, eating earthworms and insects which are harbored by the shelter in the pits (piles of leaves in the shady corners, bits of board and bark, old sacking, and low weeds); in the spring they may get an occasional frog, for any that become available are put into the pits; but their main food is fish. Fish obtained at market is cut into pieces of suitable size and tossed to the snakes or (if coaxing is necessary) offered on the end of a bamboo stick. During the years with which this paper is concerned (1932–37 inclusive) the snakes were well fed. Two, or sometimes three, times a week they were given all that they would eat. Generally, feeding has not been begun until after mating (at the end of April) and has ceased at about the end of September, when the snakes

become sluggish in the cool days of autumn. A regular schedule has not been followed, for feeding on a cold or rainy day was found to be a waste of effort and fish, but fairly regular feeding has been maintained. The yearly growth and good condition of the snakes indicate that they are well nourished.

The males are all kept in one pit, but in general the females are separated from one another, though each may share a pit with some immature or unmated snakes. All snakes are marked so as to be identifiable. At mating time the male is dropped gently into the female's pit and observed until copulation and separation have occurred, when he is moved to another female or returned to the males' pit.

MATING

The dates of controlled matings have ranged from March 22 to May 13,[1] but most have fallen in the later part of April. Early matings are possible in warm spells in March and the first days of April (as observed in nature and in the pits), but to accomplish them experimentally is not easy, as one must be free to put aside other duties when the rare suitable hour arrives. Matings may take place in very early May, too; but after a certain number of good days have been allowed to pass unused the snakes seem to lose the necessary impulse, and one or both fail to respond. Many times on bright warm days in early May a male has been brought to an unmated female only to have them show complete indifference. But on bright April days, with a temperature near 70°, successive matings have easily been secured. The snakes are then intensely alert to each other, and not infrequently copulation takes place within a few minutes of the time that the male is placed in the pit with the female. Occasionally a male has copulated with two and even three females in quick succession. Matings of the same day offer a chance for comparing periods of development.

PERIOD OF DEVELOPMENT OF THE YOUNG

In the period between copulation and birth occur: the preparation of the egg for fertilization, perhaps initiated by mating, and the migration of the egg to the oviduct; fertilization in the oviduct, prob-

[1] The snake which gave this abnormally late record had been kept in a laboratory through the winter, and apparently the seasonal rhythm of temperature was thereby disturbed for her.

ably about a month after copulation unless cold weather intervenes; and incubation during the development of the embryo. If cold weather follows copulation these events may be preceded by a dormant interval. How to recognize the divisions of this period between the beginning of preparation for fertilization of the egg and the birth of the young is not now known; consequently it is considered as a whole, without regard to when during that time fertilization takes place or how long beforehand copulation occurs, and it is here called the "period of development."

It is thought probable that the act of mating initiates the preparation of the eggs for fertilization. If the eggs were shed from the ovary and entered the oviduct for possible fertilization in the same manner whether or not mating had occurred, the exact time of mating should be immaterial, provided only that it occurred during the several weeks required for the eggs to reach the oviducts for fertilization. But it has been found that late matings produce late births. Only if preparation of the eggs for fertilization awaits the stimulus of mating (either copulation or insemination) would births be delayed, as they are, by delayed mating.

In the spring of 1934 the period of development was computed from the data at hand, and a confirmation in August was awaited. But, surprisingly, *all* the broods appeared *at once* during the last week of July, instead of during two weeks in mid-August as predicted! It was altogether the earliest season so far recorded; furthermore, it was hot, steadily hot. A connection suggested itself. Now, with the additional data of the contrasting, equally unusual, cool season of 1935, the birth records have been summarized and correlated with the temperature records at the Astronomical Observatory of the University of Michigan.

Twenty-seven normal broods born during four consecutive summers (1932–35 inclusive) are recorded here (Table I). Offspring of earlier years are not included because the mating dates are not known or because young were born under differing conditions, when the females had been moved to cages because of lack of accommodations. This shift resulted in abnormal broods, often dead at birth, and born over a period of days or weeks.

The history of the preceding season is known for all females used, with the exception of three in the series of 1934. In fifteen instances the females had mated and had had young the previous summer; in

TABLE I

Dates of Mating and of Birth of Resultant Broods of *Thamnophis sirtalis sirtalis* in the Years 1932–35 Inclusive

1932				1933				1934				1935			
Snake	Date of mating	Date of birth	No. of days between mating and birth	Snake	Date of mating	Date of birth	No. of days between mating and birth	Snake	Date of mating	Date of birth	No. of days between mating and birth	Snake	Date of mating	Date of birth	No. of days between mating and birth
A	Apr. 19	July 29	101	A	Apr. 4	July 30	117	V	Apr. 9	July 24	106	V	Mar. 22	Aug. 20	151
Q	Apr. 19	Aug. 4	107	W	Apr. 10	July 31	112	3*	Apr. 9	July 24	106	B	Mar. 22	Aug. 22	153
N	Apr. 19	Aug. 11	114	V	Apr. 10	July 29	110	W	Apr. 9	July 25	107	AG	Apr. 26	Aug. 12	108
R	Apr. 20	Aug. 5	107	B	Apr. 10	Aug. 2	114	B	Apr. 9	July 26	108	1	Apr. 26	Aug. 20	116
B	Apr. 20	Aug. 10	112	R	Apr. 21	July 30	100	Q	May 1	July 24	84	3	Apr. 26	Aug. 25	121
W	Apr. 22	Aug. 6	106	P	Apr. 24	July 30	97	1*	May 1	July 26	86				
V	May 13	Aug. 24	103	AD	Apr. 29	July 29	91	AC	May 1	July 29	89				
								2*	May 1	July 30	90				

* This is one of three females whose history of the previous summer is not known. In all other instances the female was under control for the full preceding season, and there had been no chance for mating since the preceding spring.

three they had mated but had failed to bear; four females had neither mated nor borne in the season preceding the experiment; in two instances it is known only that the snakes had had no offspring. Most of these females appear in the records of two, three, or all four years of the experiment.

RECORD OF EACH YEAR, 1932–35 INCLUSIVE

1932

In 1932 six matings were made within three days (April 19–22). These gave broods over a period of fourteen days (July 29—August 11). The three matings of the earliest day (April 19) gave births at the two extremes of the fourteen-day period (one on July 29, one on August 11) and one birth between. It may therefore be concluded that this amount of variation in period of development (fourteen days) is due not to differences in time of mating but to the individuality of the snakes or to some other uncontrolled factor. Certain constantly "early" snakes had been noted before and used as indicators, giving warning as to when the bulk of the broods were due.

In this year there was also an unusually late mating, on May 13.[2] The resulting young were born late, on August 24; still, the number of days between copulation and birth (103) was within the range of variation (101–114 days) of the six females which mated at the usual time. This fact suggests that for this snake in this summer 103 days were necessary from copulation to birth, and that this brood was delayed by late mating. But as the birth date was only nineteen days later than the "average" date for the group of six, it may be estimated that this group had only nineteen days developmental start over the May 13 young; that is, their development started about nineteen days before May 13, or about April 24.

The data for this season are given in Table II.

1933

The next year, 1933, the mating dates were on the whole somewhat earlier, ranging from April 4–29 instead of from April 19–22 as in 1932. The births, too, were earlier (July 29—August 2), giving the same average period between mating and birth of young — 107 days in 1932, 106 days in 1933. This consistency in average

[2] See footnote 1, page 163.

TABLE II

PERIOD OF DEVELOPMENT AND TIME OF BIRTH OF *THAMNOPHIS SIRTALIS SIRTALIS* IN RELATION TO TEMPERATURE IN THE YEARS 1932–35 INCLUSIVE

Year	1932	1933	1934	1935
No. of instances	6	7	8	5
Dates of mating	Apr. 19–22	Apr. 4–29	Apr. 9 and May 1	Mar. 22 and Apr. 26
Dates of birth	July 29–Aug. 11	July 29–Aug. 2	July 24–26 and 24–30	Aug. 20, 22 and 12–25
Average date of birth	Aug. 5	July 30	July 25 and 27	Aug. 21 and 19
Computed date of start of development	Apr. 24	Apr. 29 or later	Apr. 29	Apr. 26 or later
No. of days of development (extremes) from computed date of start	96–109	91–95	84–90 and 86–88	108–121
No. of days variation due to uncontrolled factors	14	5	6	14
Average no. of days of development from computed date of start	104	93	87	116
Average temperature for 3-month period (May 1—Aug. 1)	67°	69.5°	71.7°	64.5°
No. of degrees hotter than 27-year average (65.7°)	1.3°	3.8°	6°	– 1.2°
No. of degrees hotter than in coolest of the four seasons (1935)	2.5°	5°	7.2°	..
No. of days shortening of period of development as compared with 1935	12	23	29	..
No. of days shortening of period of development per degree increase in average temperature	4.8	4.6	4	..
	Average 4.5			

time between mating and birth, in spite of the difference in mating dates, suggests a fixed interval as the period of development. *But the earliest mating, April 4, and the latest, April 29, gave broods at the same time — July 30 and 29 respectively.* Apparently there is no advantage from the earlier mating. The fact that all births came within a five-day period (July 29—August 2) would indicate that in all females, despite differences in date of mating, the period of development started at about the same time. If this is so, and since the matings ranged from April 4 to 29, the conclusion is that development did not start before April 29.

In 1933, as in 1932, three matings of the same day gave the extremes in the season's birth dates (July 29 and August 2) and a date between (July 31), thus indicating some individual differences in the snakes or their pits.

So in 1933, instead of a period of development of 106 days (average time between copulation and birth) there is, rather, a dormant period, until April 29 at least, and then a developmental period of 93 days or less. And the consistency between 1932 and 1933 in the average period between mating and birth (107 days in 1932, 106 in 1933) is mere coincidence (depending on the date on which we happened to cause the matings), the actual periods of development being 104 and 93 days, respectively.

The data for this season are given in Table II.

1934

In the season of 1934 the eight matings were made on two dates three weeks apart (April 9 and May 1). This gave an excellent chance for comparison. *All* the births came in *July* (July 24–30)! The matings of April 9 gave young on July 24, 25, and 26; those of May 1, on July 24, 26, 29, and 30. That is, those of April 9 averaged only two days earlier (July 25) than those of May 1 (July 27), the earlier group apparently having but two days' start in spite of three weeks' advantage. It might be figured, then, that in 1934 development started two days before May 1, on April 29. This assumes that the two days in April are equivalent to the two days in July, which of course they may not be.

If, as figured, April 29 is set as the starting point of development, then the period was 87 days — April 29 to July 25 for the earlier group, and May 1 to July 27 for the second group. One could not

fail to be aware that this unusually short period was coincident with an exceedingly hot summer. No season could have been better suited to the needs of the experiment, and he would have been dull indeed who failed to take the hint.

The data for this season are given in Table II.

1935

In the next spring, 1935, a warm spell in March gave an opportunity for two extremely early matings (March 22). The other three matings of the season were exactly five weeks later (April 26). The broods from the early matings were born on August 20 and 22 (average, August 21); those of the matings of five weeks later, on August 12, 20, and 25 (average, August 19). Thus the early matings gave no advantage — in fact their births averaged two days later, a variation attributable to the individuality of the snakes or to minor differences in environment. In this season, then, we may be justified in setting April 26 (the later mating date) as the earliest date at which development could have begun. And if it began at this date, the period of development averaged 116 days — an unusually long time.

In this season, 1935, a wild garter snake was captured in copulation on March 16. Her brood was born 171 days later, on September 3. Since this was her first season of captivity in the pits it may be that the birth of her brood was delayed by conditions to which she was unaccustomed; but as the period of captivity before birth of young was almost half a year she was presumably adapted to her surroundings long before the brood was born. This is the most extended period we have observed, for birth was 130 days after the date determined for beginning of development.

The data for this season are given in Table II.

CONCLUSIONS FROM OBSERVATIONS DURING THE FOUR SEASONS 1932–35 INCLUSIVE

Very early matings (March and early April) have not resulted in earlier broods. Late matings (in May) have postponed birth by about the number of days that the matings were delayed past the last week of April, the time when the snakes ordinarily become continuously active. These facts are brought out in Figure 1 (p. 170).

The mating of May 13 in 1932 gave a birth delayed nineteen days,

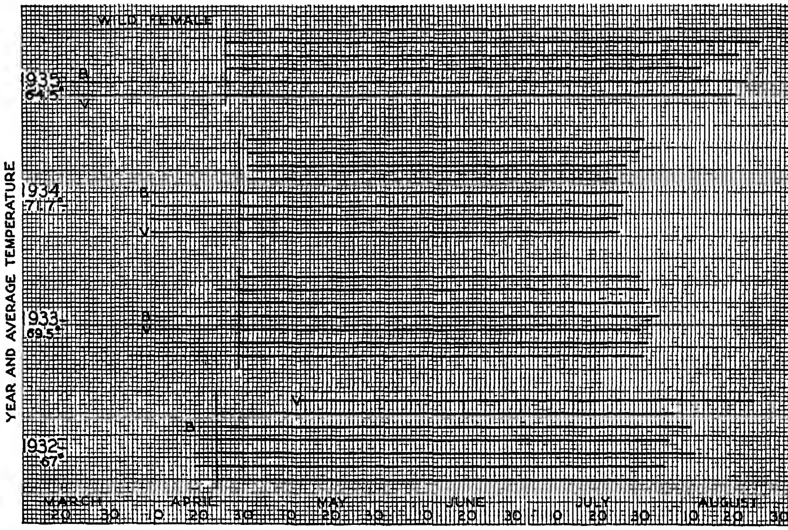

FIG. 1. Diagram showing dates of mating, birth of young, and periods of development of *Thamnophis sirtalis sirtalis* in the years 1932–35 inclusive, with average temperatures for the three-month period May, June, and July. Each horizontal line represents the record of a brood, starting at the date of copulation and ending at the date of birth. The vertical lines indicate for each year the estimated beginning of the period of development. The records of females B and V, the only snakes for which we have data for all four years, are indicated by letters. It is evident that (1) the warmer the summer the shorter the period of development, (2) very early mating does not bring about correspondingly early birth, (3) mating later than at the usual time postpones the date of birth

and those of May 1 in 1934 a handicap of two days, bringing the starting dates definitely to April 24 and 29 respectively. But the corresponding dates in 1933 and 1935 cannot be stated so certainly. We can only guess that the dates given as those *earlier* than which development did *not* start in 1933 and 1935 (April 29 and 26) are probably fairly close to the date at which it did start. Evidently under conditions of the experiment the last week in April may be considered the critical time.

But the records show that matings of late April, the common time, do not in different years produce young at the same date, and that though the periods of development may regularly begin in late April there is great variation in birth dates. In an extremely early

season (1934) the young may be born a month earlier than in an extremely late season (1935), the period of development in the early season being only three quarters that in the late season. In the four consecutive seasons recorded the days required for development have been figured as 104, 93, 87, and 116 respectively (see Table II).

TIME OF BEGINNING OF DEVELOPMENT

A weakness of these computations is that the conclusions depend directly on the estimated date of the starting of preparation for fertilization, and this has not been accurately determined. It has been assumed, for lack of information and because of working with averages, that a day at the end of the period, in August, is equivalent to one at the beginning, in April or early May, but this doubtless is not true. The error, however, must be trifling.

Also, it has been assumed that in spring there is no development until a certain day, when it suddenly starts at full speed. It may be that there is, instead, a period of slow and gradually accelerating internal activity, and that the date of actual beginning is unimportant. Yet with our usually rather sudden seasonal change about May 1, when the snakes lose their torpor and become lively again, it seems probable that there is a sudden burst of activity within them comparable to the sudden bursting of the buds on late-leafing trees which during April have shown practically no change. And the fact that in 1934 the April 9 group had an actual developmental start of only two days over that of the May 1 group shows that if activity began right after mating it was so slow as to be practically negligible or it was faster and confined to a very few days of the month. No evidence is now seen to indicate how the figures should be modified in this respect.

RECORDED TEMPERATURES OF THE FOUR SEASONS 1932–35 INCLUSIVE

The average temperatures (Fahrenheit) for the period May 1 through July 31 (practically the period of development) are as follows for the years 1932–35: 67°, 69.5°, 71.7°, 64.5°.

These figures were derived from the monthly averages recorded at the University Observatory, where the mean of the daily extremes was taken as the average for the twenty-four hours, and the average of the daily means was taken as the monthly average.

Not only was the average of the 1934 season high for the three-month period, but each separate monthly average was a highest record for the twenty-seven years recorded at the Observatory. The season was an extreme variant, being 6° hotter than the average for the twenty-seven–year period and 7.2° hotter than the coolest of our four years, 1935. Perhaps in a century one would not be favored again with two consecutive years so contrasting.

RELATION OF TEMPERATURE AND LENGTH OF PERIOD OF DEVELOPMENT

The difference of 7.2° in average temperature between 1934 and 1935 is coincident with a twenty-nine–day difference in time required for development, or four days per degree of temperature. Comparing the other two seasons, 1932 and 1933, with the cool season of 1935, we find a shortening of twelve days for 2.5° in 1932 (or 4.8 days per degree of temperature), and twenty-three days for 5° in 1933 (or 4.6 days per degree). From these four years it is concluded, then, that a variation of one degree in temperature causes a difference of four and a half days in the time of birth.

OTHER FACTORS WHICH MAY AFFECT TIME OF BIRTH

The temperatures used are those of the Observatory, nearly two miles from the Botanical Gardens. No records were made of temperatures in the pits, for it was only after a glaring correlation appeared between very early birth and such unusual summer heat that a thermometer was unnecessary to detect it, that the interest in temperatures was aroused.

But even had air and soil temperature readings been made within the pits, nothing would be known about the amount of heat absorbed by the snakes, for they were, of course, always free to lie basking in the sun or to seek cool spots under boards in the shade. As a matter of fact, it is quite possible that snakes absorb more heat when temperatures are not at their highest, for when it is cool or merely warm they seem to enjoy the sunshine, but during the hot weather they avoid it during most of the day.

Whether the average air temperature in the pits is above or below that at the Observatory is not now known. It is assumed, however, that with variation in the Observatory temperatures there is a corresponding change in the pit temperatures. Possibly on sunny

days the relation between pit and Observatory temperatures is not the same as on cloudy days. It may be that there was great variation in the amount of sunshine in the four years under consideration and that sunshine is an important factor. Perhaps maximum daily temperatures as well as average daily temperatures should be considered. In other words, it is fully realized that because of ignorance concerning them, many pertinent factors have been left out of this consideration. There is, nevertheless, a close correlation between the temperatures recorded at the Observatory and the date of birth of young in the pits.

VARIATIONS IN BIRTH DATES DUE TO THE INDIVIDUALITY OF THE SNAKES OR TO SLIGHT DIFFERENCES IN THEIR SURROUNDINGS

The variations in birth dates attributed to the individuality of the female snakes (or to minor differences among their pits) are as follows:

Year	*Average developmental period*	*Variation*
1932	104 days	14 days
1933	93 days	5 days
1934	87 days	6 days
1935	116 days	14 days

As would be expected, the shorter the period of development, the more concentrated the dates of births; or, the longer the development, the more scattered the births.

These variations may be due to several factors. Environments are not identical. Perhaps a slightly higher leaf pile in one pit is struck by the sunshine earlier in the morning, allowing the snake a longer basking time. Perhaps feeding is involved. Possibly the size of the brood influences the time of birth. At any rate, the records of three females, B, V, and W, each of whom remained in her own pit through three seasons, show that the snakes or the pits do have constant individuality in respect to the length of the period of development.

For three years in succession the females B, V, and W happened to be mated all on the same day; they thus afforded a chance for recording individuality. In 1933 all three mated on April 10; in 1934, on April 9; and in 1935, on March 22. This is the only such series obtained, but the results are rather convincing (see Fig. 2, p. 174). In 1933, a moderate year, V had young July 29, W two days

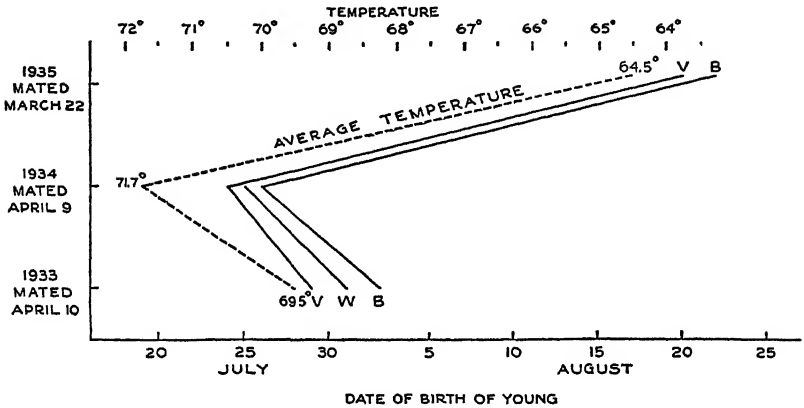

FIG. 2. Diagram showing consistency of three females of *Thamnophis sirtalis sirtalis*, V, W, and B, in regard to comparative length of periods of development of their young. In each of the three years the three females mated on the same day

later, and B two days later still. In 1934, the hot year, V had young July 24, W one day later, and B one day later than that. In 1935, the cool year, V had her brood August 20, and B two days later. The three maintained their proper sequence (except that W unfortunately died before the last record was made) and thus demonstrate a minor variation in length of period of development which is due to details of housing or, perhaps more probably, to inherent differences in the constitution or behavior of the snakes.

CONFIRMATION IN 1937 OF COMPUTED RELATIONSHIP BETWEEN TEMPERATURE AND PERIOD OF DEVELOPMENT

In 1936 the data were so scant and imperfect as to be valueless.

In 1937 three matings were successfully carried through. Young from matings of April 29, May 3, and May 3 were born August 19, 17, and 16, respectively — 112, 106, and 105 days after mating. But the first mating gave the latest brood, which indicates that development did not begin, at earliest, until the time of the later matings, i.e. May 3. Yet this is a late starting date, if we judge from the evidence of other years; consequently it seems reasonable to assume that starting was no later than this and to set May 3 as the date from which to reckon. This gives 108, 106, and 105 days, with 106 days as the average length of the period of development in 1937.

This season, instead of looking up the weather records first and then determining as before the variation in number of days with the variation in average temperature, we reversed the process, and, calculating from the periods and the scale of variation already determined from the previous years (four and a half days variation with each degree of temperature), we made a reckoning as to what average temperature should produce this result (a 106-day period). From Table II it was computed that with a period of 106 days the average temperature for the three months must have been a fraction under 67°. Compared with 1932 (temperature 67°), the period in 1937 was two days longer, that is (allowing four and one-half days for one degree) four ninths of a degree lower in temperature, or approximately 66.6°. Compared with 1935 (temperature 64.5°), it was ten days shorter, that is, about two and two ninths degrees warmer or approximately 66.7°. (These are the two years most similar to 1937.)

After thus predicting that the average for the period May, June, and July in 1937 would be found to be about 66.6° or 66.7°, we consulted the Observatory records. The average given there is 66.3°.

SUMMARY

Garter snakes living under comparatively uniform and natural conditions (in pits with thirty square feet of ground surface) have provided data on many aspects of life history, as well as on the genetical problems for which they were originally kept. The conditions in the different pits housing the snakes discussed in this paper were very similar, and constant from year to year.

In these surroundings late April is the natural time for mating, but effective copulations have occurred in a warm spell in March. After a certain number of appropriate days have passed, the snakes, though still unmated, seem to lose the necessary impulse. Sometimes a mating has been secured in early May, but only with great patience, and by that time working with the snakes is generally fruitless.

By "period of development" of the young is meant here the time between the start in the egg of preparation for fertilization (which happens probably a month after mating) and the time of birth of the young, without regard to either the point at which fertilization occurs or how long beforehand copulation takes place. It is supposed that mating may initiate the period of development.

We have found that very early matings are not followed by cor-

respondingly early births — that there is no time gained by mating before late April, when the continuously warm weather sets in. But births from matings after the beginning of the last week of April (approximately) are delayed accordingly. It is concluded that under the conditions of the experiment the period of development starts in late April and that matings in earlier warm spells are followed by developments so slow as to be negligible or by a pause until the weather warms up.

The periods of development of twenty-seven normal broods born during four consecutive summers (those of 1932–35 inclusive) are computed here, and the average for each season is compared with the average temperature of the period (May, June, and July) as recorded at the University Observatory.

In the different years the computed period of development has varied greatly — from 87 days in 1934 (an extremely hot summer) to 116 days in 1935 (an unusually cool season). The twenty-nine-day difference in the two seasons is coincident with a difference of 7.2° in the average temperatures during the periods of development, a difference of four days per degree.

From comparison of the four years under discussion, it is estimated that an increase of one degree in the average temperature brings the birth date four and a half days earlier.

University of Michigan

THE INHERITANCE OF MELANISM IN THE GARTER SNAKE *THAMNOPHIS SIRTALIS SIRTALIS* (LINNAEUS), AND SOME EVIDENCE OF EFFECTIVE AUTUMN MATING*

FRANK N. BLANCHARD AND FRIEDA COBB BLANCHARD

COAL–BLACK specimens of the garter snake *Thamnophis sirtalis sirtalis* (Linnaeus) have been collected at several localities on the shores of Lake Erie. E. B. S. Logier, of the Royal Ontario Museum of Zoology, Toronto, has reported a garter-snake population at Long Point, Norfolk County, Ontario, of whose members he judges that about one third are black (1931). Previously (1925) he recorded specimens from Point Pelee, Ontario, as did also Clyde Patch (1919). Roger Conant (1938) has had black specimens from various places in the marshes which rim the southwestern shore of Lake Erie, about a score having come to his attention; he writes that Point Place (part of Toledo on the lake shore) and Little Cedar Point are good places to find them, and that several have been taken in Toledo city parks. It would seem reasonable to suggest that further collecting may show a continuous range of the melanistic phase of this snake on the shores of Lake Erie.

APPEARANCE OF THE MELANISTIC GARTER SNAKES

These snakes may be described as completely black except for a pure white throat. From above they look velvety black, the head

* Contribution from the Department of Zoölogy, and paper No. 688 from the Botanical Gardens and Department of Botany, of the University of Michigan.

Except for a few findings of the seasons of 1938 and 1939, the facts given in this paper were known to F. N. Blanchard and the interpretations accepted by him. Beginning in 1922 the study recorded here was shared by us for fifteen years, but I have been responsible for the working of our data into a finished manuscript. Though the writing of this paper, concerned mainly with genetics, would have fallen naturally to my lot it suffers, needless to say, for lack of his suggestions and criticisms. F. C. B.

appearing iridescent. The under side of the head and throat (parts which even though they are of the lightest shade still have some color in normal specimens) are pure white, and the white is continued on several of the foremost belly scutes. Then there is an abrupt change to bluish black ventrals with lighter splotches, the light areas decreasing in size and intensity posteriorly until they disappear entirely; from that point the belly is blue-black.

The sides of the head and neck are the only parts, in the dozen specimens on which this description is based, to show a trace of the normal color pattern. The upper labials are brownish gray with black flecks; the white lower labials have a very fine dark stippling. The sides of the neck adjacent to the pure white belly scutes (the region normally of most intense color, often bright yellow or orange) are tan-gray with black flecks. This little area of brown-gray, the only sign of any color in the black snakes which we have seen, is variable in amount, sometimes hardly noticeable and sometimes extensive enough to show a trace of pattern, an indistinct stripe on the neck. Our dozen specimens in hand, and the more than a hundred young which they have borne, vary not in the quality of the black but only in the extent of the pure white at the throat and of the small amount of tan-gray on the neck, which might be expected to be sometimes extensive enough to show a normal pattern in the neck region.

When the skin is loosening for sloughing and the eyes are milky, the snakes lose their sleek glossy blackness, becoming a decidedly brownish rusty black, and the ghost of a dorsal stripe is somehow visible. At this time one would hesitate to call the snakes black. After shedding they are again velvety black.

That the distinction between black and normal pattern may be lost with preservation has been mentioned by Logier (1931). This change is comparable to that before shedding.

These melanistic snakes are black from the beginning, just as black at birth as they are as adults. In many species of snakes dark individuals grade from normal, and some darken with age, losing the bright colors and markings of their early life. Eventually they may become very dark and may be loosely called "black"; but this deepening of color is not true melanism, and the result is very different from the velvety, almost blue-black of melanistic snakes.

The intense blackness of these garter snakes is not modified in

breeding, for in broods containing both normal and black young the black are at birth just like the black ancestor, and the striped ones are perfectly normal.

AN UNSUCCESSFUL ATTEMPT TO PRODUCE A HYBRID F_2 GENERATION

The experimental hybridizing of black and normal garter snakes started with a black male caught near Ann Arbor in June, 1922 (believed to be the only black specimen known from the vicinity), and two normal females, A and B, taken in the same region in the autumn of that year. The three snakes spent the winter and spring in an enclosure together, and in August each female bore a brood of normal, striped young. These two broods were tended carefully.

In the following three years the same two females bore five broods of young, all striped, offspring of the black male; but, unfortunately, we depended on the two broods of the first year alone to produce an F_2 generation, and the later young were not tended so carefully, with the result that none reached maturity.

As all the F_1 broods had been entirely normal and striped, there was an expectation of segregation of striped and black in the next generation, with striped predominating — presumably in a ratio of 3 : 1. In 1927 an F_2 generation of twelve young appeared, surprising in that it contained no black individuals. This result of course led to misgiving as to the parentage of the F_1 snakes, suspicion that the black snake was not father of the 1923 broods. In 1928 there were two more F_2 broods, from females descended from B with males descended from A, one of eight young, one of nine — all striped. In 1932 another F_2 brood (this time from parents which were both from A) still failed to give any black ones. Table I (p. 180) records the crosses of the 1923 offspring of females A and B which, on the assumption that black is a recessive character, were expected to produce some black young.

It happened that those which reached maturity of the 1923 brood from A were males (except female C) and that those from B were females, so that most of the F_2 broods were necessarily descended from both A and B. One, however, that of 1932, was from A alone.

The fact that the 1932 brood, both of whose parents were offspring of A, was entirely normal shows that melanism, if a simple recessive, was not carried by A's 1923 brood. There was no F_2

TABLE I

RECORD OF THOSE PROGENIES FROM THE 1923 OFFSPRING OF FEMALE GARTER SNAKES A AND B (SUPPOSEDLY F_2 GENERATION FROM THE BLACK MALE) WHICH WERE EXPECTED TO SHOW A REAPPEARANCE OF THE BLACK PHASE (IN THE PROPORTION OF 3 STRIPED TO 1 BLACK IN THE FOUR F_2 GENERATIONS AND 1 STRIPED TO 1 BLACK IN THE THREE BACKCROSSES)

The absence of black individuals in the second generation indicates that the original black male confined with these females from the autumn of 1922 was not the father of their broods born in 1923, as had been supposed.

Year	Generation of brood	Female *	Male *	Young (all striped)	Unfulfilled expectation of ratio of striped to black
1927	F_2	F_1 L from B † or F_1 C from A	F_1 D or E from A †	12	3 : 1
1928	F_2	F_1 H from B	F_1 E from A	8	3 : 1
1928	F_2	F_1 M from B	F_1 D from A	9	3 : 1
1932	F_2	F_1 C from A	Sib D	13 ‡	3 : 1
1932	Backcross to black ♂	F_1 H from B	Black TB	8 ‡	1 : 1
1932 1934	Backcross to black ♀	V V	F_1 D from A F_1 D from A	12 51	1 : 1

* The snakes referred to and their origins are as follows:

Collected	*Raised in captivity*
Original black ♂, caught near Ann Arbor in June, 1922 TB, new black ♂, caught near Toledo in 1930 A ♀ (striped), caught near Ann Arbor in autumn, 1922 B ♀ (striped), caught near Ann Arbor in autumn, 1922 V ♀ (black), caught near Toledo and captive since 1930	C, D, E } from A, 1923 H, L, M } from B, 1923

† Not realizing that these little snakes had reached maturity, we had kept an F_1 group together during the summer; accordingly, when this brood was born, we could only say that it was an F_2 from the original females. Though the exact parentage was not known a record of the appearance of the females led to the conclusion that the mother was L (from B), rather than C (from A); the father, whichever individual he was, was of the 1923 brood from A. So presumably this brood was descended from both A and B.

‡ This brood was born under unnatural conditions, during a period of six weeks instead of all on a single day. The young died at birth or before, but there was no trouble in determining the color.

brood from B alone. If melanism was carried by B's 1923 brood, though not by A's, the F_2 generation descended from both A and B could not contain black, for A's offspring were pure dominants. This leaves the possibility that B's offspring did carry melanism. A backcross of her offspring to a black snake throws some light on this. Unfortunately the original black male had died, and the conclusions must rest on the assumption that the new black male (TB, from near Toledo) had the same black factor as did the original one used in the experiment, which there is no reason to doubt, nor yet perhaps any reason to believe. If this factor was the same the young from a black snake mated with B's 1923 offspring should show whether the latter carried melanism — if they did the progeny should be of striped and black in equal numbers, if not they should all be striped. The backcross of this nature shown in Table I (F_1 ♀ H (from B) × black ♂ TB) produced only normal young, indicating that B's 1923 brood did not carry melanism.

Thus it appears that there was no black in the constitutions of the 1923 broods of either A or B (or at least in those members of the broods which became parents), and that the black male was not the parent of the broods though he alone was confined with the females since the autumn of 1922. Evidently both females had mated before they were caught in the autumn, and the autumn insemination was effectual for the following summer's broods.

AUTUMN MATING

Evidence of effective autumn mating has been obtained several times. A group of six females collected on October 29, 1933, was deprived of the chance for spring mating in 1934. One of these females bore a brood of twenty-two young on August 1, 1934; and on August 7 a brood of seventeen young was borne by another. In 1936 several females were caught very late in the autumn, as near as possible to the time of hibernating. Of this group six lived successfully through the winter and following summer. Of the six one had a brood of thirteen young on August 19; another dropped fourteen large hard yolks on September 10; the others gave no young, and dissection in late autumn showed neither embryos nor yolks. Again, in the summer, 1938, a female collected the previous autumn gave a brood with no mating after capture.

It is well known that these snakes often show mating behavior

in the autumn, and actual copulation has been seen. In the fall of 1936 a spontaneous copulation was observed in a pit in which a number of males and females had been together for several weeks. Two normal matings were secured on September 29, 1933, by introducing a male into the female's pit, as is done for the spring matings. One of the two females died during the winter. The other, which had been in copulation for only nine minutes — a doubtfully sufficient period — gave no brood the following summer, but neither did she from a normal spring mating the next season.

It is supposed that insemination is the stimulus to growth of the eggs, which several weeks later enter the oviduct and are there fertilized. If autumn mating results in a progeny, either it must be early enough for the eggs to have several weeks in which to reach the ovary, where, fertilized, they remain dormant during winter; or, as is perhaps more likely, the sperm must live through the hibernation period so that fertilization occurs in the spring.

That sperm can remain functional in the female from autumn to spring is easy to believe. Young can be produced by a copulation made during the very early spring in an abnormally warm spell which is followed by the normal cold weather; this shows that sperm can survive in the female during at least a short hibernation. For example, on March 22, 1935, the temperature [1] reached 60°, and mating occurred. After this warm spell there was a period of cold weather, and the temperature did not again reach 60° until April 19, when 64° was recorded. The broods from the matings of March 22 were born no earlier than those from matings of five weeks later (April 26), a fact which indicates that the sperm were merely harbored in the female during a brief period of hibernation. Such an occurrence makes it easy to imagine autumn mating being effectual.

Thus, though the autumn mating of the females A and B in 1922 set us back many years in the genetical problem of the inheritance of melanism and retarded us in getting a segregating F_2 generation, something equally valuable was thereby learned. It will be interesting to know how frequently mating occurs in the autumn, how likely it is to be effectual, and whether it prohibits a spring mating or if two copulations may precede one brood.

[1] Daily maximum temperature as recorded at the Astronomical Observatory of the University of Michigan.

TABLE II

RECORD OF BLACK FEMALE GARTER SNAKE V

Year	Date of mating	Duration of contact (in min.)	Mate	Date of birth of young	Young			Length in mm. in Sept.
					Total	Alive	Color	
1932	May 13*	..	D (normal)†	Aug. 24	12	11	normal	760
1933	Apr. 10	..	TC (black)	July 29	23	22	black	830
1934	Apr. 9	24	D (normal)	July 24	51	51	normal	...
1935	Mar. 22	15	Brown (abnormal in color but not black)	Aug. 20	43	43	normal	848
1936	May 1	18	Brown (abnormal in color but not black)	No brood				886
1937	May 3	..	2–1 (appearing normal but carrying black factor)‡	Aug. 17	48	48	26 normal, 22 black	...

* The snake was kept, in a cage, in room temperature throughout the winter of 1931–32, and the abnormally late mating in 1932 may have been made possible by her abnormal winter experience. In no other instance have we secured mating so late in May.

† See Table I. This male was a member of A's 1923 brood, which was expected to carry melanism but was shown by breeding to be normal.

‡ This normally striped male was born in 1931 in the brood of ♀ A (normal) × ♂ TB (black).

INHERITANCE OF MELANISM

When, in the summer of 1927, suspicion first arose that the 1923 broods were not the offspring of the black male it was too late to repeat the work, for the black male died that autumn (1927). But in 1931 we were enabled to start again, with black snakes from the vicinity of Toledo, kindly supplied by Mr. Conant.

The second attempt to learn the manner of inheritance of melanism was made with three black snakes: two males, designated TB and TC, and one large female, V (whose record is given in Table II). The normal striped specimens used (all females but one) were caught

near Ann Arbor or Detroit, except one, which came from near Cheboygan in northern Michigan. The one striped male, recorded here as "Brown," was of an unusual color and pattern, and, in fact, was not really striped. The general color was grayish fawn or taupe, and instead of stripes it had only a lateral series of occasional dark spots, giving an appearance not even resembling that of a normal garter snake. It was collected by Miss Lena M. Jessman at Ecorse (near Detroit); later another male of the same color pattern was received from the same place. Though this snake was not of usual color and pattern it was normal in respect to the factor for blackness. No snakes of normal pattern from the regions where blackness commonly occurs have been used in this work, for they might carry a recessive factor.

In brief the findings are as follows:

1. In the progenies of about fifty observed matings of striped garter snakes from the vicinities of Ann Arbor and Cheboygan, Michigan, no black ones have appeared.

2. A single mating between two black individuals, both from near Toledo, produced a brood of twenty-three young, all black.

3. Ten crosses between black and striped snakes (nine crosses were striped ♀ × black ♂; one was black ♀ × striped ♂) all gave progenies entirely normal in color, showing that black is not dominant.

4. An F_2 generation (from the F_1 from striped ♀ × black ♂) consisted of six young, of which four were normal and two black — which is as close to the 3 : 1 ratio of simple Mendelian segregation as can be obtained from six individuals.

5. Two backcrosses (black ♀ × striped hybrid ♂ of the F_1 generation) both gave mixed broods, one of nine striped and twelve black, the other of twenty-six striped and twenty-two black. These ratios (9 : 12, 26 : 22, total 35 : 34) are satisfactorily close to the Mendelian expectation of 1 : 1 in a backcross to the recessive parent.

Table III summarizes the successful crosses involving black and hybrid individuals.

Evidently the three black snakes from Toledo were of the same constitution in respect to melanism, for had they not had the same factor for black the matings between them would have given striped young.

TABLE III

A Record of Crosses in the Years 1931–37, Inclusive, in a Successful Attempt to Discover the Manner of Inheritance of Melanism in the Black Garter Snakes Found near Toledo

Cross	Year	Female*	Male*	No. of young	Color of young
Black ♀ × black ♂	1933	V	TC	23	black
Black ♀ × striped ♂	1935	V	Brown	43	striped
Striped ♀ × black ♂	1931	A	TB	30	striped
	1933	A	TB	50	striped
	1931	B	TB	24 (?)	striped
	1932	R	TB	23	striped
	1933	R	TB	28	striped
	1933	W	TB	38	striped
	1936	B	TC	44	striped
	1934	7,8–0	TC	22	striped
Striped hybrid ♀ × striped hybrid ♂	1936	0–2,7,19	0–2,7,16	6	4 striped, 2 black (3 : 1 ratio)
Black ♀ × striped hybrid ♂	1937	V	2–1	48	26 striped, 22 black
	1937	0–2,3,16	2–1	21	9 striped, 12 black (1 : 1 ratio)

* The snakes referred to and their origins are as follows:

Normal	*Black*	*Hybrid, striped*
A, B, W — caught near Ann Arbor	V, TB, TC — from Toledo	0–2,7,19; 0–2,7,16 — offspring of W × TB, 1933
Brown, from near Detroit	0–2,3,16, offspring of V × TC, 1933	2–1, offspring of A × TB, 1931
7,8–0, from near Detroit (?)		
R, from near Cheboygan		

From these recorded crosses it is concluded that the melanism of the black garter snakes in the vicinity of Toledo depends on a single Mendelian recessive factor.

IDENTITY OF THE FACTOR FOR BLACK IN THE TWO LOCALITIES

In order to find out whether the factor for black in the snakes from Ontario is the same as that in the Toledo snakes, several matings were made in the spring of 1938. Unfortunately, three

matings of a black male from Ontario failed to give young, evidently because of some incapacity of the male, and the only cross to result in a brood in August was that of a black female from Ontario and a striped male, one of whose parents was a black snake from Toledo. If these two carried the same factor the young should be black and normal in equal numbers. If they had different recessive factors for black the young should all be striped, for each parent would carry a normal factor to dominate the recessive factor for black in the other parent. The brood which was born gave a perfect 1 : 1 ratio — twelve normal, twelve black — showing that if both factors are recessive they are one and the same factor.

But unfortunately the Ontario factor has not yet been shown to be recessive. If it is dominant, and the female used in the cross under discussion is a pure dominant, all the young should be black; if, however, she is a heterozygous dominant the young should be black and normal in equal numbers, as they were.

Thus we are left with two possibilities — that the factor for black in Ontario is dominant, which seems unlikely, as the factors at Toledo and Ann Arbor are recessive, or that it is recessive and the same as that at Toledo, which seems far more probable.

BROODS FROM WILD BLACK FEMALES COLLECTED AFTER MATING

Logier has several times (1929, 1930) reported on broods from black garter snakes taken in Ontario on the north shore of Lake Erie at Point Pelee and at Long Point, where garter snakes were "very abundant and melanism exceedingly prevalent" (1929). The broods which he obtained from females caught after their natural mating do not show simple Mendelian ratios, as do those from controlled matings.

If the black factor of the Ontario snakes is the same as that of the Toledo snakes the black females which he caught would be expected to have broods all black if the mate had been a black male, all striped if the mate had been a homozygous striped male, or black and striped in equal numbers if the mate had been a heterozygous striped male. But instead they gave such ratios of striped to black as 20 : 4, 21 : 13, 13 : 13, 5 : 15, 2 : 10, and 1 : 13.

Two records of broods from collected black females of Toledo have been given us by Mr. Conant, with the following ratios of striped to black: 12 : 4, 10 : 4.

These ratios do not match those resulting from controlled matings and would be hard to explain in a Mendelian manner. The findings from wild collected females suggest that the Mendelian ratio is obscured in some way. A possibility which suggests itself is that more than one male parent is represented in the brood. There are several ways in which this might come about. Might not a brood be contaminated by a previous mating, by some sperm being carried over for a year in the female? Might not a female copulate with two males at once? Might she not mate twice in the spring, or in the autumn and then again in the spring?

It is thinkable that the appearance of a few striped young in a brood otherwise all black might be the result of contamination from the mating of the previous spring; that sperm might be carried over a season in the female and so contaminate the next year's brood; that a black female bearing a striped brood fathered by a striped male one year might, the next year, mating with a black male, produce a black brood in which occurred a few striped individuals whose parent was the striped male of the previous season. But our breeding experiments give no evidence of this. We have in fact observed the very series of matings suggested here (see Table II): a black female bore an entirely striped brood by a striped male; the next year she bore an entirely black brood by a black male, and the next year again a striped brood by a striped male. Two chances thus existed for the appearance of contamination, if such a thing can be, by the survival of sperm from a previous spring mating; but no contamination resulted. Furthermore, a female kept over a season without mating does not have young. There has been no evidence of sperm living in the female from one spring to the next. A score of females which produced young one summer have in the next summer, without mating, produced none. About half of these females had mated in the wild and produced the young in captivity, but the remaining half were known to have mated in the spring preceding the birth.

That mating with two males simultaneously might occur and be responsible for an irregular ratio of black and striped young was shown by an incident noted in the spring of 1938. Ordinarily, in order to control the matings, only one male at a time has been placed with the females. But one day when the weather was cool enough to make it doubtful whether working with the snakes would be worth while, two males were put into a pit with two females for a speedy

test. At once both males became very active, and presently both were in actual copulation with one female. This lasted for a few minutes. Though one male was forced off, or voluntarily dropped away, before his mating could have been effectual, the incident did suggest a simultaneous double mating as a possible cause of apparently irregular ratios of normal and black young in the broods of collected females.

That effective mating may happen in the autumn is known; but we have no evidence as to whether or not a female which mated in the autumn will copulate again in the spring. If this should occur we should expect to get all kinds of irregular ratios in the resulting broods — though of course the character would nevertheless be following simple Mendelian inheritance.

Two separate spring matings of a female (the subject discussed in the following paragraphs), simultaneous mating with two males, and autumn mating (which it is now known may be effectual) followed by a second impregnation in the spring (an occurrence of which there is no evidence as yet available) are the explanations here offered for the irregular ratios of striped and black young recorded by Logier.

SECOND MATINGS

There is now (1939) evidence that two separate spring matings may precede a brood, though from the work of the earlier years recorded in this paper it was concluded that this does not happen. Frequently in this earlier work a male had been placed in a pit where there was a female which had recently mated as well as the one with which it was desired that he should mate; thus there existed a chance for a second copulation by a female. But because of the genetical side of the study a second mating was undesirable and was somewhat guarded against, possibly at the expense of behavior observations. It always happened, when such a chance did occur, that it was the unmated female which was courted. Only once was there an apparent exception — when a female which had been disturbed during copulation and had separated from the male after only five minutes did again copulate, a week later. According to our observations and records the first copulation presumably had not reached the point of impregnation. It seemed that a female once impregnated did not copulate again.

In 1939 there was an attempt to learn more about this in order

to explain the broods of the wild black Ontario snakes. On a day in April when conditions were very favorable and the snakes especially alert and energetic a male had been put into a pit with two females, one of which had mated nineteen days before (on April 4). It was expected that he would ignore this one, but he chanced to find her first, started courtship at once, and very quickly was in copulation. For the sake of genetical interests he was at once removed; but because of the importance of the incident in connection with understanding the irregular ratios from wild black females opportunities were made for a repetition of the occurrence. On April 27 (four days later) this female again had a chance to mate, when three males were placed in the pit housing her and two other females; and very soon she was again in copulation. This spring two more such double matings occurred, after intervals of fourteen and six days.

It is important to note, however, that in each of the three instances there is some doubt as to the effectiveness of the first mating. The female discussed above produced no young in the summer even though twice in copulation of sufficient duration. The male with which she first mated (April 4) produced no young from a mating with another female, on April 22, so it seems likely that he was not a possible parent, and there may have been no insemination preceding her second copulation; and the second copulation was interrupted before there could have been insemination, so none may have preceded the third mating. Thus it is not shown by this instance that a female will mate again after one successful mating and so produce a mixed brood, from two males.

In the second instance of repeated mating a black female from Ontario mated with a black male from the same region on April 13, the attachment lasting for seventeen minutes, about an average time. Two weeks later (April 27) she mated again, this time with a striped male from near Ann Arbor, the attachment lasting for ten minutes, which has often been shown to be a sufficient period. This is the very combination suggested to account for the irregular broods from natural matings in Ontario. And there was indeed such a mixed brood borne by this female: on August 8 a progeny of sixteen was found (two living, fourteen dead in their membranes), probably born August 6. The living young were striped, but of the fourteen which did not escape from the membrane, two were unquestionably

black, and another, already partly destroyed, was presumably black. It must be assumed that the striped male from near Ann Arbor does not carry a recessive factor for blackness, as no striped snake from this region has ever been found to carry it. If the factor for black is recessive in the Ontario snakes the first mating, of the two blacks, should have produced black young, and the second mating, with the striped male, should have produced striped young. The brood should therefore be mixed, the ratio of the two types depending only on the number of functioning sperm from each male. The young accorded with this expectation. If the black factor is recessive, both males must have been represented in the progeny.

But there are two disturbing considerations. First, in the Ontario snakes the factor for black has not yet been shown to be recessive, and if it is dominant the young from the first mating, black by black, alone might give a mixed brood (though the black young would be expected to predominate or to about equal the striped). Second, the black male, which was caught in 1937, mated readily in 1938 and 1939 but produced no young, though the females with which he mated were all presumably fertile, for they had young in 1937. It would seem strange that there should be two or three of his young in this brood when his several other matings entirely failed to give progeny. When this factor for black has been shown to be recessive, however, as is that in the Toledo snakes, there will be no possible conclusion but that this mixed brood was the offspring of two males and that the female did copulate a second time after at least a slight insemination. It should be added, though, that since there were not more than three young of the first mating, it may be that the female did not then receive the usual quantity or quality of seminal fluid.

In the third instance of two matings by a female (with an interval of six days between), only eight young were born, an exceedingly small brood for a female of size to bear thirty or forty or even fifty young, indicating that the first insemination may not have been adequate for a full brood even assuming that it alone was responsible for the progeny, as there is reason, not here presented, to believe.

It has been shown, then, that under certain conditions a female will mate a second time. But as in each recorded instance of such second mating the adequacy of the insemination, if any, at the first copulation is questionable, and as there are many observations of an already mated female (which later bore a brood of normal number)

evidently evading a second courtship, it cannot now be said that after one complete impregnation a female may mate again. Perhaps it will be found that two normal inseminations may precede a brood, and both males be well represented in the brood. But perhaps a second copulation is more likely if (or occurs only if) the first was interrupted before insemination was complete, or took place in the autumn, or involved a young male or one for some reason sterile or not fully fertile.

Though it has not here been proved that any brood following two matings actually represented two male parents, there is, in two of the three instances, good reason to believe that the first male was represented, though by only a few young. The possibility of this happening often is thought evident enough to warrant suggesting it as the explanation of the odd ratios of striped and black young in the broods of collected females at Long Point.

SUMMARY

1. Melanistic garter snakes, coal-black with pure white throats, have been found at several places on the north and west shores of Lake Erie — in Ontario at Point Pelee and Long Point (where, according to Logier, about one third of the population is black) and at various places in the vicinity of Toledo, where Conant has seen about a score.

2. An attempt to produce an F_2 generation by hybridizing black and normally colored (striped) garter snakes, which started in 1922 with a black male caught near Ann Arbor, was unsuccessful. The broods of two normal females caught in the autumn and confined with this male until birth of their young the following summer failed to transmit the black character. Apparently these females were already inseminated when they were caught in the autumn, and their broods of the following summer were not offspring of the black male.

3. This assumption of effective autumn mating has since been tested with females caught in the autumn and not allowed to mate the following spring. Several such females have borne young at the usual time.

4. A second attempt to study the inheritance of melanism with several specimens from Toledo showed that blackness is inherited in simple Mendelian fashion (the factor for black being recessive) as follows:

		F_1	F_2
Striped ♀ × striped ♂	⟶	striped	
Black ♀ × black ♂	⟶	black	
Black ♀ × striped ♂ or Striped ♀ × black ♂	⟶	striped ⟶	3 striped : 1 black
Black ♀ × F_1 striped ♂	⟶	1 striped : 1 black	

5. If the factor for black in the Ontario snakes, also, is recessive (as is probable, since it is so in both the Ann Arbor snake and those from Toledo), it is the same factor that occurs in the Toledo snakes, for a cross between a black female from Ontario and a Toledo hybrid male produced a brood giving a 1 : 1 ratio.

6. Broods from Ontario females mated in the wild show very irregular ratios of striped and black (ranging from 20 : 4 to 1 : 13), which cannot be accepted as purely Mendelian. These irregular ratios suggest the possibility that more than one male is represented in the brood. This might be brought about by: autumn mating (now known to be effective) followed by a second impregnation in the spring (which has not yet been observed); copulation with two males simultaneously (which has been seen); and two separate spring matings (observed several times in 1939 though not before). None of these occurrences has yet, however, been clearly demonstrated to produce a progeny representing two male parents. Contamination of a brood by the mating for the previous brood is by experimental evidence ruled out as a probability.

For genetical studies and behavior observations of snakes of this kind it is evidently quite necessary to start with animals which have been under control for a year. Unless the history of the preceding late summer and autumn is known the spring records are useless.

A genetical understanding of the broods occurring in nature will require more studies of mating procedure and further testing of factors. One thing, however, is now clear: the factor for blackness of the Toledo garter snakes is a simple Mendelian recessive. In the field of genetics another demonstration of Mendelian inheritance is not in itself noteworthy; but in herpetology a demonstration of Mendelian inheritance is a novelty.

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THE SENOCULIDAE OF PANAMA

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UP TO the present time only three species of Senoculidae have been recognized from Panama: *Senoculus canaliculatus* F. Cambridge, *S. purpureus* (Simon), and *S. valentinei* Petrunkevitch. Banks (1929) found no Senoculidae in his collection of 1924 from Panama. Of the forty-four mature individuals now in my possession six were taken in 1934, nineteen in 1936, and nineteen in 1939. By far the most common species found in Panama appears to be *S. canaliculatus* F. Cambridge. Cambridge gave no written description but depended entirely upon a good figure of the epigynum and an entirely inadequate figure of a part of the palpal tarsus. It appears unlikely, however, that females in my collection having epigyna so closely resembling the one figured by Cambridge can be anything but members of the same species. In spite of the inadequacy of Cambridge's figure of the male palpus it seems most probable that the males associated with females which I have regarded as identical with *S. canaliculatus* also belong to that species. Moreover, my males agree well with the description of *S. valentinei* Petrunkevitch. My present conclusion is, therefore, that *S. valentinei* is a synonym of *S. canaliculatus* F. Cambridge, and it is so treated in this paper. In view of the lack of a carefully prepared account of the female of this species I have given here a complete description, just as with new species. Unfortunately, *S. purpureus* (Simon) is not now identifiable; it must, therefore, be omitted for the present from my keys and is not again referred to in this paper. Five new species are recognized, as follows: *Senoculus barroanus*, sp. nov.; *S. bucolicus*, sp. nov.; *S. robustus*, sp. nov.; *S. silvaticus*, sp. nov.; *S. tigrinus*, sp. nov.

Knowledge concerning life histories, habits, and behavior of the Senoculidae is very meager indeed. F. Cambridge (1897–1905) wrote as follows: "The spiders themselves have the habit of lying quite flat on the bark of trees, moving with great rapidity, being remarkably Sparassiform in appearance, and they make an elongate

silken egg-cocoon." I have found these spiders on the bark of trees, but more commonly have shaken them from saplings, bushes, and vines. The first *Senoculus* I ever saw was a female adhering to a branch of a bush beside the Snyder-Molino Trail on Barro Colorado Island. She was covered by many dozens of recently hatched spiderlings, which were clinging to her body in the manner of the young in the Lycosidae. Several times I have seen females with egg cocoons fastened to a partly rolled dead leaf that was suspended by one or two threads six or eight inches long. From observations made on captive specimens it seems probable that the usual behavior for the female ready to deposit eggs is to lay down three or four short cross threads between twigs and then to hang a dead, loosely curled leaf by one thread several inches long. The eggs are laid in an oval mass on the under surface of the leaf and covered over by a mat of silken threads. The mother remains to guard the eggs and also, later, the spiderlings for a few days. She usually flattens herself over the cocoon with the first two pairs of legs outstretched in front and the two posterior pairs extended behind. Attitude and coloration thus combine to give the animal and its cocoon excellent concealment.

Methods of measuring and describing new species treated in this paper are essentially the same as those used in the author's earlier publications on Panamanian spiders (Chickering 1937a, 1937b, 1940).

Acknowledgments are again gratefully made to the directors of the Horace H. and Mary A. Rackham Fund, through whose generous support of my work the study and collection of spiders in Panama during the summers of 1934, 1936, and 1939 as well as the publication of numerous recent papers has been possible, and to Mr. Nathan Banks and Miss Elizabeth B. Bryant, both of the Museum of Comparative Zoölogy at Harvard College, who have frequently extended the courtesies of their laboratories to me. Without the help of these supporters and friends my work of recent years would have been greatly retarded.

KEY TO THE SENOCULIDAE OF PANAMA

MALES

1. Distinct retrolateral spine at base of cymbium; distinct beaklike process on retrolateral side of palpal bulb; prominent retrolateral finger-like process on palpal patella .... *Senoculus bucolicus*, p. 203
1. Palpal structures not as given above for *S. bucolicus* 2

2. Viewed ventrally palpal tibia wider than long; not laterally compressed; with three retrolateral cusps surrounding a pouch *S. canaliculatus*, p. 207
2. Viewed ventrally total width of palpal tibia about equal to total length; laterally compressed; with two retrolateral processes, one of which is beaklike .... *S. barroanus*, p. 197

FEMALES

1. Main chitinized parts of epigynum distinctly converging anteriorly toward mid-ventral line 2
1. Main chitinized parts of epigynum distinctly diverging anteriorly away from mid-ventral line 4

2. Main chitinized lobes of epigynum extended anteriorly in slender projections; first and second tibiae with about nine pairs of ventral spines (some irregularity in this feature) .... *S. barroanus*, p. 197
2. Main chitinized lobes of epigynum not slender anteriorly; first and second tibiae with either four pairs or about six pairs of ventral spines (some irregularity in this feature) 3

3. Entire chitinized epigynal lobes somewhat diverging anteriorly; each lobe much longer than wide at base; first and second tibiae with four pairs of ventral spines .... *S. canaliculatus*, p. 207
3. Entire chitinized epigynal lobes nearly parallel or slightly converging anteriorly; each lobe about as wide as long; first and second tibiae with about six pairs of ventral spines .... *S. bucolicus*, p. 203

4. Each main epigynal lobe broadly extended laterally at right angle anteriorly; about as wide as long anteriorly; obliquely striated along medial half of each lobe .... *S. silvaticus*, p. 213
4. Each main epigynal lobe not broadly extended laterally at right angle anteriorly; longer than wide anteriorly; not obliquely striated along medial half of each lobe 5

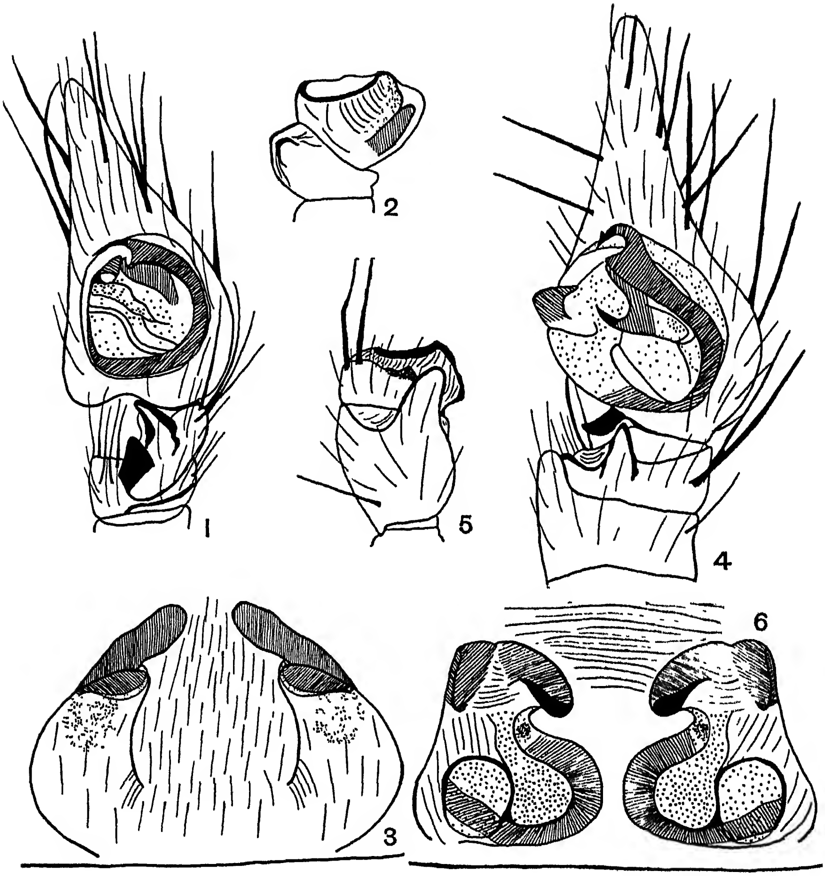
5. Each main epigynal lobe with two lobules posterior to main lobe and one broad anterior lobule .... *S. robustus*, p. 210
5. Each main epigynal lobe with but one lobule posterior to main lobe and none anterior to it .... *S. tigrinus*, p. 216

Genus SENOCULUS Taczanowski, 1872

Senoculus barroanus, sp. nov.

(Figures 1–3)

Male holotype. — Total length (body somewhat mutilated) 9.3 mm. Carapace 3.19 mm. long, 1.84 mm. wide opposite second coxae, narrowed (more gradually than is usual in this genus) to 1.41 mm. at level of LE, which project beyond margins of cephalothorax; anterior margin almost straight; moderate covering of short procumbent hair; mixture of brownish and white hair around



EXTERNAL GENITALIA OF SPIDERS

(Figures 1–6)

1. *Senoculus barroanus*, sp. nov., male palpus, ventral view
2. *S. barroanus*, sp. nov., male palpus, patella and tibia, retrolateral view
3. *S. barroanus*, sp. nov., epigynum
4. *S. bucolicus*, sp. nov., male palpus, ventral view
5. *S. bucolicus*, sp. nov., male palpus, patella and tibia, retrolateral view
6. *S. bucolicus*, sp. nov., epigynum

eyes; black bristles along margin everywhere except posterior part contiguous to abdomen; prominent tuft of yellowish hair at each anterolateral angle; prominent median longitudinal thoracic furrow; very low and flat from PME posteriorly.

Eyes. — Both rows very strongly recurved, ALE close to PLE. Anterior row almost as wide as posterior row. Ratio of eyes AME : ALE : PME : PLE = 7 : 3 : 8 : 8. AME separated from one another by five sevenths of their diameter, from ALE by twenty-three sevenths of their diameter. PME separated from one another by nine eighths of their diameter, from PLE by eighteen eighths of their diameter. Laterals separated by nine sixteenths of diameter of PLE. Central ocular quadrangle wider behind than in front in ratio of 24 : 16, very slightly longer than wide behind. AME on slightly raised tubercle; LE on more conspicuously raised tubercle. ALE pearly white, irregularly oval; all others dark and circular. Width of clypeus equal to radius of AME.

Chelicerae. — Not produced, parallel, of moderate size and robustness, not gibbous in front; basal segment 0.86 mm. long; well-developed boss. Fang of moderate size, evenly curved, very finely dentelated along inner margin. Promargin of fang groove with three rather small teeth, middle one largest; retromargin with three larger teeth. Moderately well developed scopula only along promargin.

Maxillae. — Parallel, longer than wide in middle in ratio of 34 : 15, only slightly concave along outer margin, not dilated apically. Palp inserted into middle third. Serrula marginal and confined to anterolateral angle. Moderately well developed scopula only along anteromedial angle.

Lip. — Longer than wide in ratio of 26 : 14. Basal excavations extend about ten twenty-sixths of length of organ, which reaches two thirds of length of maxillae. Anterior end somewhat narrowed so that whole lip is less rectangular than usual. Nearly straight anterior margin, provided with a group of stiff converging bristles. Sternal suture straight.

Sternum. — Longer than wide in ratio of 28 : 17, widest at interval between second and third coxae, considerably narrowed anteriorly and then widened a little contiguous to lip, terminating posteriorly in a sharp point that is not extended between fourth coxae, which are separated by one tenth of their diameter.

Legs. — 1243. Tibial index of first leg 7, of fourth leg 9.

	Femora	Patellae and tibiae	Metatarsi	Tarsi	Totals
		(All measurements in millimeters)			
1.	4.78	6.49	4.72	1.50	17.49
2.	4.04	5.51	4.04	1.42	15.01
3.	1.96	2.08	1.62	0.86	6.52
4.	4.17	4.41	3.41	1.28	13.27
Palp	0.92	0.25 + 0.23	...	1.23	2.63

Ventral spines of first and second tibiae 2 – 2 – 2 – 2 – 2 – 2 – 2 – 2 – 2 – 0; of third tibiae 1p – 1p – 1p; of fourth tibiae 1p – 2 – 0 (there is some irregularity among these). Ventral spines of first and second metatarsi, seven along prolateral side and eight along retrolateral side (a cursory examination would probably result in recording eight pairs); of third metatarsi 2 – 1p – 1p; of fourth metatarsi 2 – 2 – 1r. Ventral spines of first and second legs very long and robust, as usual in this genus. Trichobothria observed as follows: only three or four on tarsi, several irregularly placed on metatarsi, and many on tibiae, all on dorsal sides of segments named. Three claws throughout; proclaw with eight or nine slender teeth, proximal two or three very slender and crowded; retroclaw with six or seven slender teeth. All legs have many spines not recorded here and all have fairly complete coating of short brown hair and scanty supply of long light hair. Fourth legs and, to a lesser extent, third legs with ventral brushes of hair on metatarsi and distal halves of tibiae.

Palp. — Both patella and tibia very short, the former slightly longer than the latter. Patella wider than long, with very short, retrolateral nodule representing apophysis, which appears in certain species. Tibia compressed and somewhat extended ventrally, where there are low ridges and eminences. Also a shallow retrolateral excavation (Figs. 1–2).

Abdomen. — Longer than wide in ratio of 54 : 10, widest at base, diminishing gradually to posterior end; only slightly flattened. Anal tubercle a flattened cone. Spinnerets as usual in genus. Impossible to see colulus or tracheal spiracle because of mutilation.

Color in alcohol. — Yellow ground color of various shades, under parts all lighter. Cephalothorax, chelicerae, and legs dorsally light amber. Cephalothorax with black around eyes and broad dusky brown margin. Dorsum of abdomen light yellow with several very narrow irregular dark stripes along each lateral side; elongated dark spots dorsally. Legs with dark irregular dorsal blotches.

Female allotype. — Total length 10.41 mm. Carapace 3.31 mm. long, 2.21 mm. wide opposite second coxae, 1.65 mm. wide at level of PLE, which project slightly beyond margin; anterior border nearly straight; short brown hair either sparsely developed or worn off in handling; a few white hairs in region of eyes; longitudinal thoracic groove a shallow basin; low and flat throughout.

Eyes. — Both rows of eyes very strongly recurved, AME close to anterior margin, ALE very small and close to PLE. Two rows almost equal in length. Ratio of eyes AME : ALE : PME : PLE = 5 : 2.5 : 7.5 : 8. AME separated from one another by six fifths of their diameter, from ALE by twenty-eight fifths of their diameter. PME separated from one another by twenty-one fifteenths of their diameter, from PLE by forty-five fifteenths of their diameter. Laterals separated by a little more than one half of diameter of PLE. Central ocular quadrangle wider behind than in front in ratio of 5 : 3, as long as wide behind. AME on low eminence; LE on common tubercle, with small ALE clinging to anterior border. ALE pearly white, irregularly oval; all others dark, regularly circular. Height of clypeus equal to about four fifths of diameter of AME.

Chelicerae. — Not produced, fairly robust, somewhat gibbous in front near base; basal segment 1.10 mm. long; well-developed boss. Fang of moderate size, evenly curved. Promargin of fang groove with three teeth, middle one largest (only two teeth on left side); retromargin with three larger teeth close together, middle one slender, others more robust. Well-developed scopula only along promargin.

Maxillae. — Very slightly divergent, longer than wide in middle in ratio of 40 : 16, only slightly concave along outer border, slightly dilated apically. Palp inserted between basal and middle third. Marginal serrula extending from scopula over apical outer angle. Scopula confined to apical medial angle.

Lip. — Longer than wide in ratio of 27 : 15. Basal excavations extend about twelve twenty-sevenths of length of organ, which reaches about five eighths of length of maxillae. Considerably narrowed in apical third; slightly or not at all notched apically. About ten or twelve stiff black converging apical marginal bristles. Sternal suture straight.

Sternum. — Longer than wide in ratio of 29 : 17, widest between second coxae, narrowed to 10 units (as compared to 17) between

first coxae, and then apparently widened again and extended to meet lip at sternal suture.

Legs. — 1243. Tibial index of first leg 10, of fourth leg 10. Legs somewhat mutilated.

	Femora	Patellae and tibiae	Metatarsi	Tarsi	Totals
		(All measurements in millimeters)			
1.	4.78	5.51	4.04	0.98	15.31
2.	4.04	5.14	3.37	1.00	13.55
3.	2.21	2.19	1.41	0.90	6.71
4.	4.29	4.29	2.82	1.10	12.50

Ventral spines of first tibiae 2 – 2 – 2 – 2 – 2 – 2 – 2 – 2 – 2 – 0 (last pair replaced by pair of terminal bristles); of second tibiae, nine prolateral and eight retrolateral spines, not all definitely paired (also with pair of bristles replacing terminal pair of spines); of third tibiae 1p – 1p – terminal prolateral bristle and a row of retrolateral spines suggesting a comb for some special purpose; of fourth tibiae 0 – 1p – row of five stiff terminal bristles (weak spines). Ventral spines of first and second metatarsi, seven prolateral and eight retrolateral, not all definitely paired and none terminal (difficult here to distinguish between lateral and ventral spines); of third metatarsi 2 – 1p – 1p; of fourth metatarsi 2 – 2 – 0. Ventral spines of first and second legs very long and robust. Tarsus and tibia of palp very spiny; palpal claw with several short teeth. Trichobothria apparently distributed as in male but exact determination difficult because many seem broken off. Three claws throughout; proclaw and retroclaw probably with nine teeth in a single row. Legs with little hair, but some of original coating may have been worn off. Fourth tarsi and metatarsi with moderately well developed brushes.

Abdomen. — Longer than wide in ratio of 58 : 14, widest about one tenth of distance from base; somewhat distorted but probably considerably flattened in life. Anal tubercle a flattened cone. Spinnerets normal to genus. Colulus and tracheal spiracle not visible because of distortion.

Epigynum. — Considerably different from that of any other species I have studied. Most characteristic feature is presence of two slender anterior converging extensions of chitinized lobes (Fig. 3).

Color in alcohol. — Somewhat lighter than male. Cephalothorax with only narrow dusky brown margin. Abdomen without irregu-

lar dark stripes along lateral sides and with only a few dark spots on dorsum and none on legs dorsally.

Type locality. — Male holotype from Canal Zone Forest Reservation, Canal Zone, Aug., 1936. Female allotype from Gamboa, Canal Zone, Aug., 1939. Male paratypes from Barro Colorado Island, Canal Zone, July, 1934, and Aug., 1939, Canal Zone Forest Reservation, Canal Zone, Aug., 1939.

Senoculus bucolicus, sp. nov.

(Figures 4–6)

Male holotype. — Total length (from clypeus to posterior end of anal tubercle) 8.21 mm. Carapace 3.19 mm. long, widest opposite second coxae, where it is 2.70 mm. wide, sharply narrowed to 1.47 mm. at level of PLE, which occupy almost full width of head at that level; covered with moderately well developed coat of brownish procumbent hairs; white hairs around eyes; deep longitudinal thoracic furrow; very flat, much depressed in region of thoracic furrow.

Eyes. — Both rows of eyes strongly recurved and very characteristic of genus. Posterior row longer than anterior row in ratio of 55 : 49. Ratio of eyes AME : ALE : PME : PLE = 6 : 4.5 : 11 : 11. AME separated from one another by five sixths of their diameter, from ALE by nineteen sixths of their diameter. PME separated from one another by nine elevenths of their diameter, from PLE by twelve elevenths of their diameter. Laterals separated by six elevenths of diameter of PLE. Central ocular quadrangle wider behind than in front in ratio of 5 : 3, wider behind than long in ratio of 25 : 24. AME on slightly raised tubercle; LE on somewhat more prominent confluent tubercle. ALE pearly white; all others dark. Height of clypeus equal to five sixths of diameter of AME.

Chelicerae. — Not produced, fairly robust, parallel; basal segment 0.95 mm. long; boss well developed. Fang normal, evenly curved, rather finely dentelated along inner margin. Promargin of fang groove with three teeth, middle one largest; retromargin with three larger teeth. Moderately well developed scopula only on promargin.

Maxillae. — Very slightly convergent, longer than wide in ratio of 36 : 19, only slightly concave along outer margin, not dilated apically. Palp inserted into second quarter from base.

Lip. — Longer than wide in ratio of 23 : 15. Basal excavations reach little less than half way to distal end. Nearly rectangular. Sternal suture straight.

Sternum. — Longer than wide in ratio of 27 : 21, widest at interval between second and third coxae, pointed behind but not extended between fourth coxae, which are separated by one third of their diameter. Long black bristle in the middle of each coxa on ventral side.

Legs. — 1243. Tibial index of first leg 9, of fourth leg 11.

	Femora	*Patellae and tibiae*	*Metatarsi*	*Tarsi*	*Totals*
		(All measurements in millimeters)			
1.	4.41	5.64	4.53	1.96	16.54
2.	4.04	5.02	4.29	1.98	15.33
3.	3.68	3.06	2.70	1.47	10.91
4.	2.70	3.80	3.70	1.72	11.92
Palp	1.34	0.26 + 0.49	...	1.41	3.50

Ventral spines of first and second tibiae 2 – 2 – 1r – 2 – 2 – 2 – 0; of third tibiae 1p – 1p – 1p; of fourth tibiae 0 – 2 – 0. Ventral spines of first and second metatarsi, five prolateral and six retrolateral, with much irregularity of position; of third metatarsi 2 – 2 – 1p – 1p; of fourth metatarsi 2 – 1p – 1p – 1r – 0. Ventral spines on first and second legs very long and robust. Trichobothria distributed as follows: four pairs on tarsi, several on metatarsi, and many on tibiae. Three claws throughout; proclaw apparently with six slender teeth; retroclaw with five (?). Legs clothed with scantily arranged long hairs and considerable short brown hair. Weakly developed ventral brushes of hairs on third and fourth metatarsi and tibiae as described for *S. valentinei* Petrunkevitch.

Palp. — Patella and tibia very short. Patella with short blunt retrolateral apophysis. Tibia with well-chitinized low semicircular ridge on anteroventral surface and two low retrolateral processes forming shallow groove between them. Tarsus with strongly chitinized retrolateral spur at its base; distal half of tarsus long and slender. Bulb provided with several processes, as shown in Figures 4–5. Fourteen heavy spines on cymbium.

Abdomen. — Longer than wide in ratio of 36 : 12; rather flat (it is possible that a part of flattening is due to distortion). Anal tubercle a prominent cone. Colulus a low broad distinct cone. Anterior spinnerets robust, with their bases separated by colulus;

middle spinnerets small, contiguous; posterior spinnerets longest, with terminal segment more than half as long as basal segment. Tracheal spiracle just anterior to base of colulus.

Color in alcohol. — Under parts all more or less yellowish, with palpal tarsus deep amber. All eyes encircled with dark brown or black pigment with only little color around AME. Carapace yellowish. All appendages yellow dorsally. Abdomen generally darker yellowish; body wall just over heart region quite transparent and colored by organs within; almost all of dorsal abdominal area except median transparent region provided with numerous angular yellowish chalky spots. In a paratype third legs irregularly black ventrally on last three segments.

Female allotype. — Total length 9.19 mm. Carapace 3.51 mm. long, 3.06 mm. wide opposite second coxae, abruptly narrowed to 1.84 mm. at level of PLE, which occupy slightly more than thirteen fifteenths of width of head at that level; anterior border almost a straight line; covered with moderately heavy coat of reddish brown hair with a few black hairs intermixed and a few white ones in region of eyes; deep thoracic furrow; very low throughout and depressed in region of thoracic furrow.

Eyes. — Both rows of eyes very much recurved and distinctly characteristic of genus. Posterior row longer than anterior row in ratio of 30 : 27. Ratio of eyes AME : ALE : PME : PLE = 6 : 3.5 : 11 : 11. AME separated from one another by five sixths of their diameter, from ALE by twenty-five sixths of their diameter. PME separated from one another by ten elevenths of their diameter, from PLE by fourteen elevenths of their diameter. Laterals separated by five elevenths of diameter of PLE. Central ocular quadrangle wider behind than in front in ratio of 29 : 15, wider behind than long in ratio of 29 : 27. AME on low common tubercle; LE on somewhat more prominent common tubercles. ALE pearly white; all others dark. Height of clypeus equal to about five sixths of diameter of AME.

Chelicerae. — Fairly robust, somewhat gibbous in front, not produced, parallel; basal segment 1.35 mm. long; boss well developed. Fang rather robust, evenly curved, dentelated along inner margin. Promargin of fang groove with three teeth of moderate size; retromargin with three much larger teeth. Moderately well developed scopula only on promargin.

Maxillae. — Parallel, longer than wide in ratio of 2:1, almost straight along lateral margin, not dilated apically. Palp inserted into second quarter from base. Marginal serrula only along outer anterolateral angle. Well-developed scopula on inner anterolateral angle.

Lip. — Longer than wide in ratio of 32:20. Basal excavations reach almost exactly half of length of organ. Distal margin very slightly concave and provided with row of stiff converging bristles. Sternal suture slightly procurved.

Sternum. — Longer than wide in ratio of 29:25, widest between second coxae, pointed behind but not extended between fourth coxae, which are separated by about one third of their diameter. Long black bristle in center of third and fourth coxae (may be present on other coxae in life).

Legs. — 1243. Tibial index of first leg 9, of fourth leg 11.

	Femora	*Patellae and tibiae*	*Metatarsi*	*Tarsi*	*Totals*
		(All measurements in millimeters)			
1.	4.04	5.51	3.77	1.60	14.92
2.	3.68	4.90	3.43	1.47	13.48
3.	2.74	3.19	2.70	1.23	9.86
4.	3.80	3.78	3.55	1.48	12.61

Ventral spines of first tibiae 2 – 2 – 1r – 2 – 2 – 2 – 0 (with an extra one on both legs between second and third on retrolateral side); of second tibiae 1p – 2 – 1r – 2 – 2 – 2 – 0 (left), 2 – 2 – 1r – 2 – 2 – 2 – very heavy bristles which might be called weak spines (right); of third tibiae 1p – 1p – 2 (weak); of fourth tibiae 0 – 1p – 2 (weak). Ventral spines of first metatarsi 2 – 2 – 1r – 2 – 2 – 2 – 1 (median); of second metatarsi 2 – 2 – 1r – 2 – 2 – 2 – 1 (median); of third metatarsi 2 – 0 – 1 (median); of fourth metatarsi 2 – 1p – 1r – 2 (small). Ventral spines of first and second legs very long and robust. Trichobothria apparently in four pairs on tarsi but numerous on metatarsi and tibiae. Three claws throughout; retroclaw with five slender teeth; proclaw with six. All legs with scantily distributed long hair and much short brown hair. Third and fourth tibiae with distinct ventral brushes; third and fourth metatarsi with weakly developed ones. Palpus with tarsal claw having four teeth.

Abdomen. — Longer than wide in ratio of 45:15; much flattened. Anal tubercle a broad flat cone with a tuft of reddish brown hair

ventral to it. Colulus obscured by wrinkles but probably present as a fairly conspicuous cone. Anterior spinnerets robust, not contiguous at their bases, which are separated by what is considered to be colulus. Middle spinnerets small, slender, obscured by others; posterior spinnerets longest, with terminal segment one half as long as basal segment; much reddish hair. Tracheal spiracle just anterior to colulus.

Epigynum. — With two strongly chitinized hooks whose broad bases are very close together; provided with several ridges and grooves (Fig. 6).

Color in alcohol. — Essentially as described for male except that ventrally third tibiae and metatarsi are almost black and third tarsi have black prolateral stripe.

Type locality. — Male holotype and female allotype from Barro Colorado Island, Canal Zone, July, 1936. Male paratypes from Barro Colorado Island, Canal Zone, July, 1934, 1936, 1939. Female paratypes from same locality, June–July, 1934.

Senoculus canaliculatus F. Cambridge

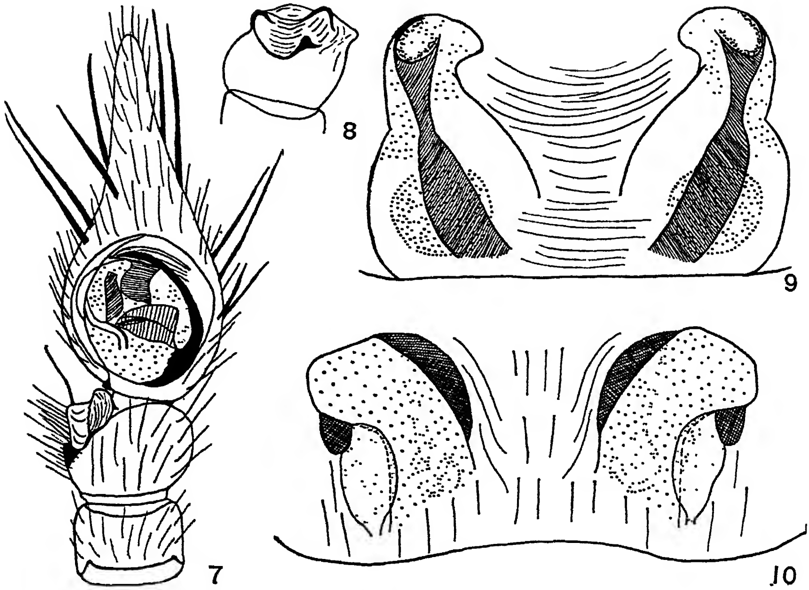
Senoculus valentinei Petrunkevitch, 1925.

(Figures 7–9)

In view of the lack of a careful description of the female of this species I am providing one here, just as for a new species. My figures of the male palpus and the epigynum (Figs. 7–9), also, are given here for comparison with those published by Cambridge (1897–1905) and Petrunkevitch (1925).

Female. — Total length 12.74 mm. Carapace 4.29 mm. long, widest opposite second coxae, where it is 3.30 mm. wide, narrowed abruptly at level of PLE to 2.08 mm.; posterior row of eyes occupy almost full width of head at that level; anterior border nearly straight; covered with moderately heavy coating of brown procumbent hair; stiff bristles along margins and especially along anterior border; white hairs in vicinity of eyes; tuft of hairs at each anterolateral angle; fairly deep longitudinal thoracic furrow; very low and flat, with head region only slightly raised.

Eyes. — As usual in this genus both rows of eyes very strongly recurved and ALE very small and close to PLE. Posterior row only slightly wider than anterior row. Ratio of eyes AME : ALE :



EXTERNAL GENITALIA OF SPIDERS

(Figures 7–10)

7. *Senoculus canaliculatus* F. Cambridge, male palpus, ventral view
8. *S. canaliculatus* F. Cambridge, male palpus, tibia, retrolateral view
9. *S. canaliculatus* F. Cambridge, epigynum
10. *S. robustus*, sp. nov., epigynum

PME : PLE = 6 : 4 : 11 : 11. AME separated from one another by slightly less than their diameter, from ALE by six times their diameter. PME separated from one another by slightly more than their diameter, from PLE by twenty-five elevenths of their diameter. Laterals separated by six elevenths of diameter of PLE. Central ocular quadrangle wider behind than in front in ratio of 30 : 14, almost as long as wide behind. AME on low tubercle; LE on somewhat more prominent common tubercle; ALE free from head below. ALE pearly white and oval; all others circular and dark. Width of clypeus slightly less than diameter of AME.

Chelicerae. — Not produced, robust, parallel, gibbous in front; basal segment 1.72 mm. long; well-developed boss. Fang fairly robust, evenly curved, dentelated along inner margin. Promargin

of fang groove with three teeth of moderate size, middle one largest; retromargin with three larger teeth. Moderately well developed scopula on promargin.

Maxillae. — Parallel, longer than wide in ratio of 27 : 13, slightly concave along outer border, not dilated apically. Palp inserted into second quarter from base. Marginal serrula confined to anterolateral angle. Well-developed scopula confined to anteromedial angle.

Lip. — Longer than wide in ratio of 43 : 21. Basal excavations extend to about middle point of organ, which reaches two thirds of length of maxillae. Almost straight across distal border; group of stiff converging distal bristles. Nearly rectangular. Sternal suture straight.

Sternum. — Longer than wide in ratio of 40 : 26, widest opposite interval between second and third coxae, considerably narrowed anteriorly, terminating posteriorly in a rather sharp point that is not extended between fourth coxae, which are separated by five thirteenths of their diameter.

Legs. — 1243. Tibial index of first leg 10, of fourth leg 12.

	Femora	*Patellae and tibiae*	*Metatarsi*	*Tarsi*	*Totals*
		(All measurements in millimeters)			
1.	5.00	6.68	3.92	1.35	16.95
2.	4.41	5.39	3.31	1.38	14.49
3.	2.82	3.19	2.48	1.23	9.72
4.	4.29	3.98	2.94	1.35	12.56

Ventral spines of first and second tibiae 2 – 2 – 2 – 2 – 0; of third tibiae 1p – 1p (?) – 0; of fourth tibiae 0 – 2 (irregular) – 0. Ventral spines of first and second metatarsi 2 – 2 – 2 – 2 – 0 (ventral spines may easily be confused with laterals); of third metatarsi 2 – 1p – 2 (?); of fourth metatarsi 2 – 2 – 2. Ventral spines of first and second tibiae and metatarsi very long and robust. Trichobothria observed as follows: double row of five or six in each row on tarsi and metatarsi; numerous on dorsal side of tibiae; apparently forming fringe on prolateral surface of third femora. Three claws throughout; proclaw with seven slender teeth; retroclaw with six teeth. All legs with many spines not recorded here, and last two segments of palps with many long spines irregularly placed. Also palpal distal claw with five slender teeth. All legs with fairly thick covering of short brown hair and rather scanty supply of much longer, lighter-

colored hair. Palps quite hairy. Fourth legs with distinct ventral brushes on metatarsi and tibiae.

Abdomen. — Longer than wide in ratio of 7:3, not so slender as in most species from Panama; in this species tending to be swollen dorsally and laterally about midway. Two small rounded dorsal tubercles about one quarter of distance from base and a single larger median prominence slightly behind middle of dorsal area usual in these females but may be entirely lacking. Colulus a fairly prominent cone with tracheal spiracle just a short distance anterior to it. Spinnerets normal to genus.

Epigynum. — Two main lobes somewhat divergent; anterior ends directed medially (Fig. 9).

Color in alcohol. — Under parts all more or less yellowish. Chelicerae and palpal tarsus amber-colored. Dorsally all appendages darker yellow with brown spots in some specimens. Margin of carapace brownish. Eyes surrounded with dark brown or black pigment. Dorsally abdomen shows transparent cardiac stripe and reddish brown mottling irregularly overlying yellowish ground color. Also many small chalky whitish angular spots all over dorsal area except cardiac stripe. Brown coloration marked in a specimen from Porto Bello, and almost lacking in some taken on Barro Colorado Island.

Collection records. — This seems to be the most common *Senoculus* in Panama. I have specimens in my collection as follows: males — Barro Colorado Island, June, 1936, Aug., 1936 and 1939, Fort Randolph, Aug., 1936, Fort Sherman, Aug., 1939; females — Barro Colorado Island, July, 1936, June and July, 1939, Fort Davis and Porto Bello, Aug., 1936, Canal Zone Forest Reservation, July, 1939, Madden Dam, Aug., 1939.

Senoculus robustus, sp. nov.

(Figure 10)

Female holotype. — Total length 12.50 mm. Carapace 5.15 mm. long, 4.16 mm. wide at level of second coxae, almost round behind posterior eyes, narrowed to 2.82 mm. at level of LE, which occupy twenty twenty-thirds of its width; anterior margin nearly straight, with lateral corners rounded; well-developed coat of mixed short brown and yellowish procumbent hair; white hairs on the deeply

pigmented areas around eyes; posterior three fifths of lateral margin with fringe of brown bristles and long light yellowish hair, anterior two fifths with longer light yellowish hair; longitudinal thoracic furrow short, deep, and broader than usual; low and flat, with head only slightly raised.

Eyes. — Both rows strongly recurved, ALE small and close to PLE. Posterior row wider than anterior row in ratio of 45:43. Ratio of eyes AME : ALE : PME : PLE = 5.5 : 3 : 11 : 12. AME separated from one another by about seven fifths of their diameter, from ALE by about eight times their diameter. PME separated from one another by fifteen elevenths of their diameter, from PLE by thirty elevenths of their diameter. Laterals separated by seven twelfths of diameter of PLE. Central ocular quadrangle wider behind than in front in ratio of 36 : 16, only slightly longer than wide behind. AME slightly raised and directed somewhat laterally; LE on low confluent tubercles; ALE free beneath. ALE pearly white and somewhat oval; all others circular and dark. Width of clypeus equal to about seven fifths of diameter of AME.

Chelicerae. — Not produced, robust, essentially parallel, gibbous in front; basal segment 1.84 mm. long; well-developed boss. Fang robust, evenly curved, finely dentelated along inner margin. Promargin of fang groove with three teeth, middle one largest, others rather small; retromargin with three teeth, outermost one somewhat more robust than other two. Quite well developed scopula only on promargin.

Maxillae. — Parallel, fairly robust, longer than wide in middle in ratio of 33 : 14, slightly concave along outer border, not dilated apically but somewhat pointed in middle of anterior border. Palp inserted into second quarter from base. Marginal serrula extends over outer half of anterior border. Well-developed scopula along inner half of anterior border and long curved hairs along outer margin.

Lip. — Longer than wide at base in ratio of 24 : 15. Basal excavations extend to middle of organ, which reaches two thirds of length of maxillae. Nearly straight across distal border; group of converging black distal bristles. Nearly rectangular. Sternal suture straight.

Sternum. — Longer than wide in ratio of 21 : 15, widest opposite second coxae, narrowed to one third its length between first coxae, terminating posteriorly in a sharp point that is not extended between

posterior coxae, which are separated by about one fourth of their diameter.

Legs. — 1243. Tibial index of first leg 11, of fourth leg 14.

	Femora	*Patellae and tibiae*	*Metatarsi*	*Tarsi*	*Totals*
		(All measurements in millimeters)			
1.	5.39	7.23	4.29	1.59	18.50
2.	4.90	6.13	4.04	1.59	16.66
3.	3.55	4.04	3.19	1.35	12.13
4.	5.02	5.01	3.55	1.59	15.17

Ventral spines of first and second tibiae 2 – 2 – 2 – 2 – pair of terminal bristles; of third tibiae 1p – 1p – 4 retrolateral weak spines in a transverse row; of fourth tibiae 1p – 2 – 3 weak retrolateral spines in a transverse terminal row. Ventral spines of first and second metatarsi 2 – 2 – 2 – 0; of third metatarsi 2 – 1p – 1p; of fourth metatarsi 2 – 2 – 2. Ventral spines of first and second legs quite long and robust. Tibia and tarsus of palp very spiny. Palpal claw with about seven slender teeth increasing in length from basal tooth. Three claws throughout; proclaw with about six teeth; retroclaw with six. All legs with moderately well developed coat of short brown hairs; femora, especially of first two pairs of legs, with conspicuous long light yellowish hair giving shaggy appearance to this species.

Abdomen. — Longer than wide in ratio of 64 : 20; width about same to posterior end, where it is gradually narrowed to base of spinnerets; considerably flattened. Anal tubercle a flattened cone. Spinnerets normal to genus. Colulus soft and weakly developed. Small tracheal spiracle just anterior to colulus. Well-developed coat of short, light-colored hair, with short weak sparsely arranged bristles and considerable long light hair along lateral sides.

Epigynum. — Characterized by two massive strongly chitinized lobes, not hooklike, diverging as shown in Figure 10.

Color in alcohol. — Under parts generally light yellowish except lip, maxillae, and chelicerae, which are amber-colored. In front chelicerae darker amber. Dorsally legs light amber. Cephalothorax amber-colored and somewhat grayed by presence of hair. Dorsally abdomen has light-colored lancelike stripe over heart; irregular dark brown spot just behind cardiac stripe; many broken alternate light and dark stripes posteriorly and laterally.

Type locality. — Female holotype from Barro Colorado Island, Canal Zone, June 30, 1934. Taken with many spiderlings clinging to mother and remnants of loosely constructed cocoon in a partly curled leaf attached to bark on one of "Big Trees" on Armour Trail.

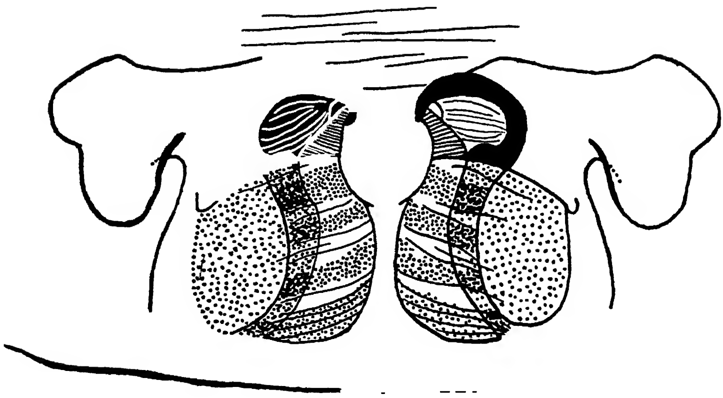
Senoculus silvaticus, sp. nov.

(Figure 11)

Female holotype. — Total length 8.58 mm. Carapace 3.12 mm. long, 2.70 mm. wide (nearly round in outline from posterior eyes to posterior margin) at level of second coxae, narrowed to 1.65 mm. at level of LE, which occupy fourteen fifteenths of width; anterior margin nearly straight but lateral corners more rounded than is usual in this genus; moderately well developed covering of short brown procumbent hair; white hairs on pigmented areas surrounding eyes; a few short dark marginal bristles along margin except at anterior border, where they are long and slender; one long bristle just ventral to AME space; fairly deep but short longitudinal thoracic furrow; low and quite flat, with cephalic portion slightly raised.

Eyes. — Both rows of eyes very strongly recurved, ALE very close to PLE. Posterior row wider than anterior in ratio of 14 : 12. Ratio of eyes AME : ALE : PME : PLE = 6 : 4 : 12 : 11.5. AME separated from one another by five sixths of their diameter, from ALE by twenty sixths of their diameter. PME separated from one another by nine twelfths of their diameter, from PLE by fourteen twelfths of their diameter. Laterals separated by ten twenty-thirds of diameter of PLE. Central ocular quadrangle wider behind than in front in ratio of 28 : 14, wider behind than long in ratio of 28 : 24. AME slightly raised and directed somewhat laterally; LE on low confluent tubercles. ALE pearly white, irregularly oval; all others dark and circular. Width of clypeus equal to seven sixths of diameter of AME.

Chelicerae. — Not produced, parallel, of moderate size and robustness; slightly gibbous in front; basal segment 1.10 mm. long; well-developed boss. Fang moderately robust, evenly curved, finely dentelated along inner margin. Promargin of fang groove with three teeth, middle one largest; retromargin with three larger teeth more closely crowded. Moderately well developed scopula only along promargin.



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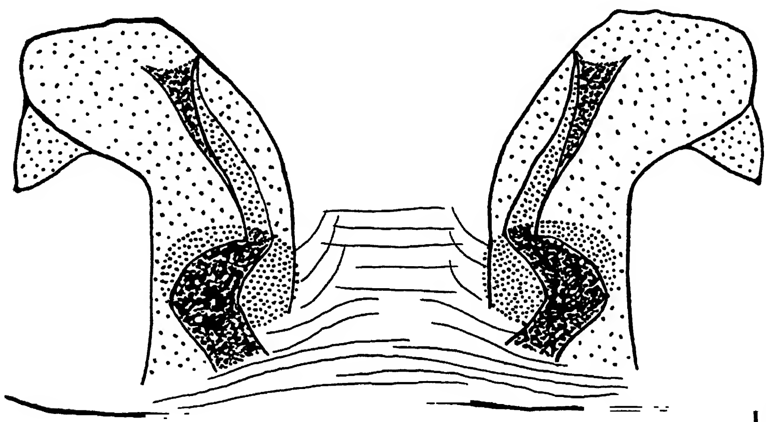

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EXTERNAL GENITALIA OF SPIDERS

(Figures 11–12)

11. *Senoculus silvaticus*, sp. nov., epigynum
12. *S. tigrinus*, sp. nov., epigynum

Maxillae. — Very slightly convergent distally, longer than wide in middle in ratio of 40:21, lateral margins straight, not dilated apically. Palp inserted into middle third. Marginal serrula only along lateral half of distal border and outer anterolateral angle. Moderately well developed scopula along medial half of anterior border and inner anterolateral angle.

Lip. — Longer than wide in ratio of 29 : 19. Basal excavations reach almost half length of organ, which extends two thirds of length of maxillae. Distal end somewhat narrowed so that whole organ is less rectangular than is frequently the case in this genus. Somewhat notched at distal end, where there is a row of converging black bristles. Sternal suture straight.

Sternum. — Longer than wide in ratio of 25 : 22, much rounder in outline than is usual in this genus, widest just posterior to second coxae, covered with moderately heavy coat of fine upright bristles, not much narrowed anteriorly, terminating in a blunt point that does not extend between fourth coxae, which are separated by one half their width.

Legs. — 1243. Tibial index of first leg 11, of fourth leg 13.

	Femora	*Patellae and tibiae*	*Metatarsi*	*Tarsi*	*Totals*
		(All measurements in millimeters)			
1.	3.55	4.17	3.00	1.47	12.19
2.	3.43	4.04	2.70	1.38	11.55
3.	2.45	2.45	2.33	1.19	8.42
4.	3.31	3.19	2.63	1.35	10.48

Ventral spines of first and second tibiae 2 – 2 – 2 – 2 – 0 (terminal spines replaced by stiff bristles); of third and fourth tibiae 1p – 1p – 0 (terminal spines replaced by pair of stiff robust bristles). Ventral spines of first and second metatarsi 2 – 2 – 2 – 1 (median); of third metatarsi 2 – 2 – 1p; of fourth metatarsi 2 – 1p – 2 – 0 (difficult to distinguish between lateral and ventral spines). Ventral spines of first and second legs very long and robust. Tarsus and tibia of palp very spiny. Palpal claw with five teeth increasing in length from small basal to rather long and slender distal tooth. Trichobothria observed as follows: a few scattered on palpal tibiae; double dorsal row of ten on tarsi; fifteen to twenty dorsal on metatarsi apparently not arranged in regular rows; many on tibiae and crowded near proximal end. Three claws throughout; proclaw and retroclaw each with five or six slender teeth. All legs provided with moderately complete coat of short brown hair and sparse long light-colored hair. Fourth tibiae with rather conspicuous ventral brushes of dark hair; remnants of brushes appear on metatarsi of fourth legs and on both metatarsi and tibiae of third legs.

Abdomen. — Longer than wide in ratio of 43 : 21, widest at about

beginning of last third, nearly cylindrical at base; somewhat flattened posteriorly. Anal tubercle with bulbous base and conical distal part. Spinnerets normal to genus. Colulus a low, soft, much-reduced cone. Tracheal spiracle just anterior to colulus.

Epigynum. — Two lobes intricately sculptured into ridges, grooves, and processes, as shown in Figure 11.

Color in alcohol. — Essentially as described for *S. barroanus*, sp. nov., except that dorsum of abdomen has considerable light reddish brown color irregularly distributed over it.

Type locality. — Female holotype from Barro Colorado Island, Canal Zone, July, 1936. Female paratype from same locality, June, 1939.

Senoculus tigrinus, sp. nov.

(Figure 12)

Female holotype. — Total length 15.07 mm. Carapace 6.15 mm. long, 4.90 mm. wide opposite second coxae, nearly round in outline posterior to PE, where carapace measures 3.06 mm. wide; posterior eyes occupy twelve thirteenths of width of head at that level; anterior margin almost straight, with tuft of yellowish hairs at each lateral corner; covering of short brown procumbent hair; numerous brown bristles along all margins except posterior margin next to abdomen, where there is a band of short white hairs; numerous white hairs in vicinity of pigmented areas surrounding eyes; long bristle just ventral to AME space; usual median longitudinal thoracic furrow apparently lacking in this species but instead a fairly deep rounded pit containing two muscle impressions; low and quite flat, with cephalic part only raised a little.

Eyes. — Both rows very strongly recurved, ALE close to PLE. Posterior row wider than anterior row in ratio of 25 : 23. Ratio of eyes AME : ALE : PME : PLE = 6 : 3.5 (long diameter) : 12 : 12. AME separated from one another by eight sixths of their diameter, from ALE by fifty sixths of their diameter. PME separated from one another by seventeen thirteenths of their diameter, from PLE by thirty-four thirteenths of their diameter. Laterals separated by eight twelfths of diameter of PLE. Central ocular quadrangle wider behind than in front in ratio of 40 : 17, slightly longer than wide behind. AME slightly raised and directed somewhat laterally; LE on more conspicuously raised confluent tubercles; ALE free beneath.

ALE pearly white and somewhat irregularly oval; all others circular and dark. Width of clypeus equal to nine sixths of diameter of AME.

Chelicerae. — Not produced, parallel, rather more robust than usual in this genus, quite gibbous in front; basal segment 2.21 mm. long; well-developed boss; long yellowish hair in front. Fang fairly robust, evenly curved, finely dentelated along inner margin. Promargin of fang groove with three fairly strong teeth, middle one largest; retromargin with three larger teeth. Well-developed scopula only on promargin.

Maxillae. — Parallel, longer than wide in middle in ratio of 38 : 17, quite concave on outer margins, not dilated apically. Palp inserted into second fourth. Marginal serrula extending over distal lateral half. Well-developed scopula along distal medial half of anterior border and medial angle.

Lip. — Longer than wide in ratio of 25 : 15. Basal excavations extend slightly more than half of length of organ, which reaches two thirds of length of maxillae. Nearly rectangular. Distal border straight, with row of stiff converging black bristles. Sternal suture straight.

Sternum. — Longer than wide in ratio of 50 : 36, widest opposite posterior border of second coxae, covered with fine upright hair and scattered long slender bristles. Anterior end not much narrowed. Posterior end terminates in sharp point not extended between posterior coxae, which are separated by about one fourth of their diameter.

Legs. — 1243. Tibial index of first leg 12, of fourth leg 13.

	Femora	*Patellae and tibiae*	*Metatarsi*	*Tarsi*	*Totals*
		(All measurements in millimeters)			
1.	6.21	7.96	4.78	1.78	20.73
2.	5.76	6.74	4.41	1.80	18.71
3.	4.29	4.53	3.55	1.72	14.09
4.	6.00	5.88	4.41	1.76	18.05

Ventral spines of first and second tibiae 2 – 2 – 2 – 2 – 0; of third tibiae 1p – 1p – 0; of fourth tibiae 1p – 2 – 0. Ventral spines of first and second metatarsi 2 – 2 – 2 – 0 (lateral spines easily confused with ventral spines); of third metatarsi 2 – 1p – 2; of fourth metatarsi 2 – 2 (?) – 1 (?). Ventral spines of first and second legs very

long and robust. Tibia and tarsus of palp very spiny. Palpal claw with seven teeth increasing in length from basal tooth. Trichobothria apparently distributed essentially as in *S. silvaticus*, sp. nov. Three claws throughout; two lateral claws each with about six or seven simple teeth in a single row. All legs with moderately well developed coat of short brown hair and scattered long yellowish hair. Brushes of hair frequently occurring ventrally on third and fourth tibiae and metatarsi in this genus apparently much reduced on third leg and subdivided on fourth tibiae into three ventral tufts.

Abdomen. — Longer than wide in ratio of 77 : 30, widest in the middle; mildly flattened. Anal tubercle flattened, with broad base. Spinnerets normal to genus. Soft, weakly developed colulus. Tracheal spiracle just anterior to colulus. At some distance in front of tracheal spiracle is transverse fold, significance of which I do not know. Good coating of short brownish hair; numerous short slender brown spines. Surface more or less pitted and grooved.

Epigynum. — Characterized by two chitinized hooklike lobes, which are slender, curved away from one another, and not intricately sculptured (Fig. 12).

Color in alcohol. — Essentially as described for *S. robustus*, sp. nov. Chelicerae deeper brown and terminal segments of spinnerets reddish brown.

Type locality. — Female holotype from Barro Colorado Island, Canal Zone, July, 1936. Female paratype from same locality, June, 1934.

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ALBION, MICHIGAN

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AGE CHANGES IN THE TEETH OF THE COTTONTAIL RABBIT, *SYLVILAGUS FLORIDANUS*

LEE R. DICE AND DORA S. DICE

THE following descriptions of the teeth of the cottontail rabbit are based mostly on specimens of *Sylvilagus floridanus mearnsii* Allen. A few specimens of the related subspecies *alacer* and *similis* have, however, also been examined. All the individuals mentioned are in the collection of the Division of Mammals, Museum of Zoölogy, University of Michigan. The drawings were made by Grace Eager.

At birth the tips of the principal incisors (I_1, I^1) in both jaws of the young cottontail are already present, but none of the other teeth have cut the gums. The molariform teeth in both jaws show prominently under the gums at this time, however, and are evidently nearly ready to erupt. We base these statements on the condition of a young *alacer* from Rago, Kansas, which died in captivity immediately after birth and which is now preserved in alcohol (No. 58279).

The incisors which are present at birth are the permanent incisors, for in no specimens of older ages is there any indication of a replacement of these teeth. On the other hand, the second pair of upper incisors are preceded by milk teeth.

The next youngest skull available to us (No. 77823) is from a young *mearnsii* taken from a nest near Ann Arbor, Michigan. In the lower jaw the incisors (I_1) show hardly any wear. The two deciduous molars (DM_3, DM_4) apparently had already cut through the gum, but are unworn. The first molar (M_1) also is well in place, and may likewise have pierced the gum. The second molar (M_2) is below the level of the alveolus. The third molar is not present, probably having been lost in the preparation of the specimen. In the upper jaw the anterior incisor (I^1) already shows a considerable amount of wear. The posterior deciduous incisor (DI^2) is present and probably was above the gum. The tips of the three deciduous

molars (DM^2, DM^3, DM^4) and of the first molar (M^1) had probably also cut the gum. The second molar (M^2) is present, but is barely above the alveolus. The third molar (M^3) is not in sight.

Another individual (No. 77829) from the same nest as the animal described in the preceding paragraph was kept in captivity for 10 days before being prepared as a specimen. The teeth reveal a considerable advance over those of the younger animal, but the artificial feeding which this rabbit received may have delayed somewhat the usual rate of growth. The lower incisors (I_1) already exhibit a slight amount of wear. The first three molariform teeth (DM_3, DM_4, M_1) show traces of wear on the cusps, and the third premolar (P_3) appears beneath its milk molar. The second molar (M_2) is barely above the alveolus, and is not yet erupted. The third molar is not present. In the upper jaw there has been a considerable amount of wear on the front incisor (I^1). The deciduous posterior incisor (DI^2) is present, and just behind it appears the tip of the permanent second incisor (I^2), which is still within its alveolus. The first four molariform teeth (DM^2, DM^3, P^4, M^1) all have traces of wear on their cusps. The third and fourth permanent premolars (P^3, P^4) are present in the alveoli below their deciduous predecessors; M^2 is not yet erupted; and M^3 is missing.

Another series is available of three skulls of young animals captured in the nest near Ann Arbor, kept as captives, and prepared as specimens one week apart. The youngest (♀ No. 75496), killed when her eyes were not yet open, was of approximately the same age as No. 77823, described above, and the teeth are in similar condition. The next older specimen (♀ No. 75497), which had the eyes open, is slightly larger than specimen No. 77829, described above, and the teeth are more worn. The oldest specimen (♂ No. 75498) was two weeks older when killed than the youngest individual, and differs in the much larger teeth. This animal was fully haired and had a total length of 142 mm., and was probably nearly ready to leave the nest. The lower incisor is well worn. The two lower deciduous molars (DM_3, DM_4) are also well worn and are about to be displaced by permanent premolars. The first two lower molars (M_1, M_2) exhibit some wear. The last molar (M_3) is present in the alveolus, but has not yet erupted. The anterior upper incisor (I^1) is well worn and has a prominent internal pit. The posterior deciduous incisor (DI^2) is still present, and the tip of the permanent posterior

incisor (I^2) is probably just erupting. The upper deciduous molars (DM^2, DM^3, DM^4) are much worn and are about to be replaced by the permanent premolars. The first two molars (M^1, M^2) show a small amount of wear. M^3 is deep in its alveolus, not yet ready to erupt.

In a specimen (No. 52708) with a total length of 170 millimeters, from Three Oaks, Michigan, all the deciduous molars are still in place. The deciduous posterior upper incisor (DI^1) is not yet lost, and the permanent posterior incisor (I^2) is still below the gum.

Two young specimens from Alma, Michigan, taken on the same day, have total lengths of 208 and 193 millimeters, and may have come from the same brood. In the smaller specimen both of the much-worn upper deciduous incisors (DI^2) are present; in the larger specimen the left one has been lost. The permanent posterior incisors are in place, and their tips have probably erupted. In the smaller specimen all the deciduous molars are present, though much worn. In the larger specimen all the deciduous molars are present except the two on the right lower jaw. The two right deciduous molars have obviously just been lost, for the two premolars are entirely unworn. The lower and upper third molars in both specimens have risen above their alveoli, but have probably not yet cut the gums.

The next older specimen available is a female from Portage Lake, Washtenaw County, Michigan (No. 53757). The animal was not measured, but it weighed 273 grams. The upper and lower third molars are both in place and show evident wear. All the deciduous teeth are gone. A male (No. 57861) with a skull of nearly the same size, from Ladysmith, Wisconsin, also has all the permanent teeth in place. This animal had a total length of 267 millimeters.

It is evident, then, that the permanent set of teeth is complete in these cottontails when the young animals have reached a total length of about 250 millimeters and weigh about 250 grams. At this time they are probably a little more than one month of age.

The patterns exhibited on the faces of the teeth by the layers of dentine, enamel, and cement change somewhat with the age of the animal. In describing these patterns we are unable to give an account of the condition of very old, worn-out teeth, because no extremely old specimen has been available to us.

There is a small amount of individual variation in the details of

enamel folding on the borders of the reëntrant angles of the molariform teeth. Except, however, for the slight changes correlated with advance in age which we here describe and except for the occasional doubling of the anterior reëntrant angle of P_3, the main features of enamel pattern on the teeth are much alike in all the specimens of this species which we have examined.

The upper first incisors (I^1) are provided with a prominent anterior groove (Fig. 1), which is present on the tooth at the birth of the animal and persists throughout life. An interior pit of enamel occurs in very young animals, but quickly disappears. The anterior face of the incisor has a heavy border of enamel, but enamel is lacking on the posterior part of the tooth. The result of wear is to give the incisor its characteristic chisel shape.

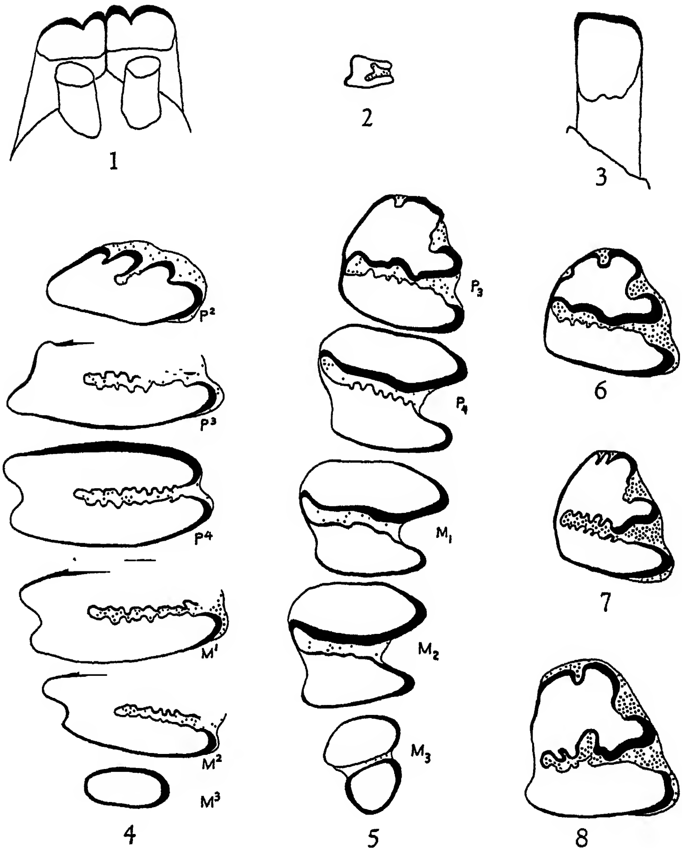
The deciduous upper second incisor (DI^2) is only a small peg, which is soon lost. The permanent second incisor (I^2) also is peglike (Fig. 1) and is completely surrounded by a thin band of enamel. This tooth is usually worn off nearly flat. It probably serves as a stop to prevent the sharp lower incisor from injuring the palate.

The most anterior upper deciduous molar (DM^2) is an oval tooth which has a strong anterior reëntrant angle. The angle is especially strong on the crown of the tooth, which it divides unequally into two cusps (Pl. I). The labial cusp is larger and stronger than the lingual one. Two shallow grooves, one on each side of the main anterior reëntrant angle, occur on the lower anterior face of the tooth. These grooves do not appear in our plate.

The upper third milk molar (DM^3) in all the specimens available to us shows a small amount of wear on the face of the tooth (Pl. I), and the characters of its cusps when first erupted cannot, therefore, be determined. The tooth, when slightly worn, has a strong lingual reëntrant angle, which bifurcates at its internal end to form an enamel Y (Fig. 2). This Y is assumed to represent a trace of an enamel crescent like those which occur on the molariform teeth of many primitive lagomorphs. The enamel of the Y seems to be at no time connected with the enamel of the exterior of the tooth, except through the reëntrant angle.

The upper fourth deciduous molar (DM^4) is similar to DM^3 in all essential characters, including an enamel Y on its face.

The anterior upper premolar (P^2) in the mature animal has three anterior reëntrant angles, each of which slopes toward the labial



ENAMEL PATTERNS ON FACES OF TEETH OF
SYLVILAGUS FLORIDANUS MEARNSII

1. Upper incisors (I^1 and I^2). No. 57109. × 6
2. Right upper third deciduous molar (DM^3). No. 75497. × 4
3. Right lower incisor (I_1). No. 57109. × 4
4. Right upper molariform teeth. No. 55174. × 6
5. Right lower molariform teeth. No. 55174. × 6
6. Right P_3, showing unusual reëntrant angle on the anterior lingual side of the tooth. No. 58305. × 6
7. Right P_3 from moderately old animal. No. 54206. × 6
8. Right P_3 from very old animal. No. 42182. × 6

side of the tooth (Fig. 4). In the newly erupted tooth (No. 53757) only the middle one of these angles has its full depth. A slight amount of wear soon discloses the two lateral angles, which, however, are only about half the depth of the middle angle. All these angles persist and become somewhat more prominent in the most aged specimens at hand. A thick rim of enamel completely surrounds this tooth. In the mature animal a layer of cement covers the anterior and lingual surfaces of the tooth and fills the anterior reëntrant angles.

The upper third premolar (P^3), when first uncovered by the removal of its milk molar, exhibits on its face an enamel crescent connecting with the inner end of the lingual reëntrant angle (Pl. I). The crescent is quickly removed by wear, and the tooth then shows the lingual reëntrant angle as its most prominent character. In the young animal the enamel on both borders of this reëntrant angle is slightly wavy. In older animals the enamel becomes more strongly crenulated (Fig. 4). At all ages the enamel of the anterior border of the angle tends to be slightly heavier and sometimes more crenulated than that of the posterior border. The enamel on the outside of the tooth is heaviest on the lingual surface and diminishes in thickness toward the labial side. Enamel is entirely lacking on the labial surface. Cement fills the lingual reëntrant angle and also covers the lingual surface of the tooth.

The upper fourth premolar (P^4) when first uncovered shows on its face traces of an enamel crescent like that on P^3. The later stages of wear on this tooth also are similar to those of P^3.

The upper first and second molars (M^1 and M^2) when first erupted appear to be two separate pillars (Pl. I), but they are joined just beneath the top of the tooth, and the connection becomes evident as soon as wear begins on the crown (Fig. 4). Parts of an enamel crescent appear fleetingly on the faces of each of these teeth. The two molars in the adult have enamel patterns very similar to those of the adjacent premolars (P^3 and P^4).

The upper third molar (M^3) is a peglike tooth at its first appearance, but with wear its face assumes an elongated form, somewhat irregular in outline (Fig. 4). Enamel completely surrounds this tooth.

The permanent lower incisor (I_1) is present at birth (No. 77823), at which time it has a prominent anterior groove. This groove quickly disappears with wear, and subsequently the tooth has the

typical chisel shape, with the anterior edge nearly straight across (Fig. 3). A heavy band of enamel covers the anterior face of the incisor, but does not extend over the posterior part.

The anterior lower deciduous molar (DM_3) when first erupted consists of two enamel pillars, on the anterior one of which there is a prominent anterior lobe (Pl. I). With wear the anterior lobe becomes merged with the anterior pillar, and is represented only by a strong labial reëntrant angle. At the latest stages of wear the two enamel pillars remain unconnected.

The posterior lower deciduous molar (DM_4) when first erupted also consists of two independent enamel pillars (Pl. I). With wear they become connected along the lingual edge of the tooth by a rim of enamel, and at this time the tooth has the same general pattern as the permanent premolar (P_4), which soon replaces it.

The anterior lower premolar (P_3), when first exposed by the removal of its milk molar, consists of two closely fused pillars (Pl. I). The anterior pillar rises a little higher than the posterior one. There is no obvious enamel pattern on the face of the tooth in our specimen (No. 62765), but only some irregular markings, which may be due in part to wear. There is no posterior lobe on this tooth, such as that which is present for a time on P_4.

At its first stage of wear P_3 is made up of two separate enamel ovals connected on the lingual edge of the tooth by a thin line of enamel (No. 53757). With continued wear the line of enamel joining the two ovals becomes doubled (No. 57109), and the tooth is then composed of two closely approximated pillars separated by a labial reëntrant angle, which completely crosses the tooth (Fig. 5). In one specimen an unusual shallow groove is present on the anterior lingual border of the tooth (Fig. 6). In old animals the main reëntrant angle becomes somewhat shorter and then fails completely to cross the tooth (Figs. 7–8). In the oldest animals available to us as specimens, however, the main reëntrant angle of P_3 does not lack very much of crossing the tooth, and it therefore never approaches the character of *Hypolagus*, in which genus the reëntrant angle extends only about halfway across.

An obtuse, posteriorly directed cape or point on the anterior lip of the main reëntrant angle of P_3 is a characteristic feature of *Sylvilagus floridanus* (Fig. 5). It is especially prominent in young animals. The portion of the anterior lip of the reëntrant angle internal to the

cape is smooth or slightly wavy in young rabbits (Fig. 5), tends to become crenulated in middle age (Fig. 7), and is often rather coarsely folded in old animals (Fig. 8). The enamel is much thicker on the anterior lip of the main reëntrant angle than on the posterior lip.

A widely open reëntrant angle occurs on the labial side of P_3 just anterior to the main reëntrant angle (Fig. 5). It extends about one fourth the way across the tooth. It appears at the first stage of wear and is present in the oldest specimens we have examined. The enamel making up this reëntrant angle is occasionally somewhat folded.

A shallow reëntrant angle appears on the anterior face of P_3 at the first stage of wear (Pl. I). With continued wear this anterior angle becomes deeper and narrower (Fig. 4). In rare specimens two anterior reëntrant angles occur side by side (Fig. 7).

Cement fills the reëntrant angles of P_3 and covers the anterior border of the tooth in a thin layer.

The lower fourth premolar (P_4) when it first appears consists of two pillars (Pl. I). There is a small lobe on the posterior border of the tooth, but it disappears as soon as wear begins. The two enamel pillars making up P_4 are at first connected only by cement (No. 31593). With a small amount of wear the two pillars become connected at the lingual side of the tooth by what appears to be a single line of enamel (No. 62765). In older specimens, however, the connecting ridge of enamel between the two pillars is obviously double (Fig. 5). The enamel around the anterior pillar is heavier than that around the posterior pillar, and therefore the posterior pillar wears down more rapidly than the anterior one. The anterior pillar, accordingly, stands higher than the posterior pillar at all stages of wear. The enamel on the anterior border of the posterior pillar (posterior lip of the reëntrant angle) is very thin and in young animals is usually slightly wavy, but in older animals it is crenulated (Fig. 5). Cement fills the reëntrant angle.

The first two lower molars (M_1, M_2) when first erupted each consist of two independent pillars (Pl. I). On the face of M_1 before it has cut the gum there may be seen on some specimens (No. 77823) a trace of the posterior cusp mentioned above as fleetingly present on P_4. In the early stages of wear the two pillars making up each of these molars become connected on the lingual side of the tooth by a thin line of enamel, and in later stages of wear this is double (Fig. 5).

The history of enamel wear on these molars therefore closely follows that on P_4.

The last lower molar (M_3) consists at all stages of wear of two independent pillars, of which the posterior one is the smaller (Fig. 5). Cement fills the space between the two pillars.

In the oldest specimens available to us there is no indication that any of the permanent molariform teeth are approaching the limit of their possible growth. All are fully hypsodont, and there is no suggestion in any of them of the formation of a root, with consequent cessation of growth.

DISCUSSION

After the young cottontail has acquired its full set of permanent teeth, probably at about one month of age, the teeth no longer offer much assistance in determining its age. In old animals the main reëntrant angle on P_3 fails completely to cross the tooth, and there is some increase in heaviness of enamel and in degree of crenulation on the internal reëntrant angles, but the differences between these characters in old and young animals are rather slight. It is possible, however, that in animals older than any we have examined the enamel patterns may show some degeneration.

The Y-shaped peninsulas of enamel which occur at an early stage of wear on the faces of DM^3 and DM^4 and the enamel crescents which are fleetingly present on the unworn crowns of P^3 and P^4 of *Sylvilagus floridanus* resemble a type of enamel pattern which was much more important in the early lagomorphs. Enamel crescents were conspicuous on many of the upper molariform teeth of the Eocene *Mytonolagus petersoni* (Burke, 1934, Pl. L); they persisted over a considerable period of wear on the Oligocene *Palaeolagus haydeni* (Troxell, 1921, Figs. 9–16); and they were perhaps of lesser importance on the Upper Oligocene *Archaeolagus ennisianus* (Dice, 1917, Fig. 1). These crescents are very prominent on some of the upper teeth of the fossil and Recent ochotonids. Crescents occur also for a brief time on some of the newly erupted upper molariform teeth of the Recent leporids *Oryctolagus cuniculus*, *Lepus timidus*, and *Sylvilagus brasiliensis* (Major, 1899, Pl. 36). We therefore interpret the enamel crescents of *S. floridanus* as fleeting vestiges of an ancestral character.

The small posterior lobe which is present briefly on the newly uncovered crowns of P_4 and M_1 of *Sylvilagus floridanus* seems also to be a vestige of a character which is important in the primitive

rabbits. Posterior lobes which persisted during a considerable period of wear were present on many of the lower molariform teeth of the Oligocene *Palaeolagus haydeni* (Dice and Dice, 1935, Figs. 8–10, 14, 15). Posterior lobes are present, however, in our modern cottontail, so far as we are able to discover, only on P_4 and M_1, and they promptly disappear when wear begins on the teeth.

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EXPLANATION OF PLATE I

Molariform teeth of *Sylvilagus floridanus mearnsii*

Magnified about 12 times.

Upper figure. Left upper molariform teeth, showing early stages of wear on the deciduous molars. The first two permanent molars are just erupting. No. 75496

Middle figure. Left lower molariform teeth of the same individual

Lower left figure. Newly uncovered right lower premolars (P_3 and P_4). No. 58953

Lower right figure. Early stage of wear on the right upper third premolar (P^3), showing trace of enamel crescent. No. 37574

DM^2 DM^3 DM^4 M^1 M^2

DM_3 DM_4 M_1 M_2

P_4 P_3

P^3

Grace Eager

Sylvilagus floridanus mearnsii

INCREASED NUMBER AND DELAYED DEVELOPMENT OF SCALES IN ABNORMAL SUCKERS

CARL L. HUBBS

THE evidence presented in this paper is a new confirmation of the thesis that the countable and measurable characters of fishes are to a large degree determined or modified by the rate of development (Hubbs, 1926a).

In preparing a report on their survey of the fishes of the Connecticut River watershed in New Hampshire Joseph R. Bailey and James A. Oliver (1940, p. 180, fig. 80) discovered a number of teratological suckers which were referred to me for identification. The variant characters seemed of sufficient interest and significance to warrant an analytical study, for which the collectors obligingly made the material available.

The abnormal suckers were collected on August 25, 1939, in Nash Bog Pond and its outlet, Nash Stream, a tributary of the Upper Ammonoosuc River of the Connecticut River system in New Hampshire. Some of the abnormal fish came from the artificial mud-bottom pond, but most of them were taken in the outlet just below the dam. The rather clear light-brown water had a temperature of 70° F. in midafternoon, when the reading for the air was the same. The current in the outlet was moderate. The bottom of rubble, boulders, silt, and muck supported a sparse and scattered growth of vegetation. Further ecological data are given on pages 21, 69, 91, and 110 of the Survey Report containing the paper by Bailey and Oliver (1940).

There is nothing particularly unusual in the local conditions that might be responsible for the abnormal characters of the suckers. Nor did an examination of the fish disclose a possible cause of the aberrancy. They do not appear emaciated; on the contrary, they are thick, deep, and pudgy, as though very well fed. As can be seen from Table IV, the abnormal specimens average larger than

TABLE I

Lateral-Line Scale Counts in Suckers from the Connecticut River System in New Hampshire

Lateral-line scales	*Catostomus commersonnii commersonnii*			*Catostomus catostomus nannomyzon*	
	Other localities	Nash Bog Pond		Nash Bog Pond	Other localities*
		Normal	Abnormal		
57	2	..	..	..	..
58	3	4	..	..	..
59	7	1	..	..	..
60	4	3	..	..	..
61	5	8	..	..	..
62	2	12	..	..	..
63	3	6	..	..	..
64	..	3	..	..	..
65	1	2	..	..	..
66	1	2	..	..	..
67	..	2	..	..	..
68	..	..	..	..	..
69	..	..	..	..	..
70	..	..	..	..	..
71	..	..	..	..	..
72	..	..	..	..	..
73	..	..	..	..	..
74	..	..	..	..	..
75	..	..	..	..	..
76	..	..	..	..	..
77	..	..	..	..	..
78	..	..	..	..	..
79	..	..	..	..	..
80	..	..	..	..	..
81	..	..	..	..	2
82	..	..	..	..	..
83	..	..	..	..	..
84	..	..	..	..	..
85	..	..	..	..	..
86	..	..	..	..	4
87	..	..	..	..	3
88	..	..	1	..	3
89	..	..	..	..	1
90	..	..	2	..	6
91	..	..	..	..	5
92	..	..	1	..	9
93	..	..	..	..	2
94	..	..	..	..	4
95	..	..	..	..	3
96	..	..	1	..	1
97	..	..	1	..	3
98	..	..	..	1	1
99	..	..	..	1	2
100	..	..	..	1	1
101	..	..	1	..	1
Number	28	43	7	3	51
Average	60.36	62.07	93.43	99.00	91.65

* Counts from Bailey and Oliver (1940), less one count of 99 scales for a specimen from Nash Bog Pond.

the unmodified individuals of the same species in the same collection. The guts, like those of the normal examples, are filled with cladocerans, a very common food of young suckers (Bigelow, 1924). Since almost precisely parallel abnormalities have been attributed to a helminth infestation (Hubbs, 1927), a search was made for internal parasites in two of the terata, but they were found relatively free of infestations. The evidence therefore negates the suggestion of Bailey and Oliver (1940, p. 180) that the abnormalities were due to

TABLE II

DORSAL-RAY COUNTS IN SUCKERS FROM THE CONNECTICUT RIVER SYSTEM IN NEW HAMPSHIRE

	Principal dorsal rays						
	9	10	11	12	13	No.	Av.
Catostomus commersonnii commersonnii							
Nash Bog Pond							
Abnormal individuals, 21 to 37, mostly 24 to 35 mm.	..	..	8	25	1	34	11.79
Normal individuals:							
16 to 24 mm.	..	7	81	57	3	148	11.38
25 to 43 mm.	..	..	20	33	2	55	11.66
Other localities	..	..	3	23	4	30	12.03
Catostomus catostomus nannomyzon							
Nash Bog Pond	..	2	1	..	..	3	10.33 ?
Other localities	6	104	3	..	..	113	9.97

parasitism or a silt diet. A genetic basis is suspected, but an environmental cause is by no means ruled out.

When the abnormal suckers were identified as *Catostomus commersonnii commersonnii*, their most striking feature (shown, however, only by the larger individuals) was an almost unbelievable increase in the number of scales (Table I). Instead of ranging from 58 to 67 (an expected range), as in the unmodified specimens of the species from this locality, the scales of the variants numbered from about 88 to 101. The counts of 96, 97, and 101 were approximately certain, whereas those of 88 to 92 were less sure (but may be taken as minimum enumerations). In the other abnormal individuals the squamation was not sufficiently developed to allow an accurate count, but in all specimens which were partially scaled posteriorly (see Table III)

the scales were of the same order of minuteness as in the specimens that were counted.

Why, then, are these abnormal suckers not referred to the fine-scaled form, *Catostomus catostomus nannomyzon*, of which three

TABLE III

DEVELOPMENT OF THE SQUAMATION IN SUCKERS FROM THE CONNECTICUT RIVER SYSTEM IN NEW HAMPSHIRE

Standard length in mm.	0			1	2			3	4	5		6		7	
	N	(A)	C	(A)	N	(A)	C	N	N	N	C	N	C	N	C
14	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..
15	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..
16	22	..	..	..	..	..	..	..	..	..	..	..	..	..	..
17	21	..	..	..	..	..	..	..	..	..	..	..	..	..	..
18	36	..	..	..	..	..	..	..	..	..	..	..	..	..	..
19	36	..	..	..	..	..	..	..	..	..	..	..	..	..	..
20	21	..	..	..	..	..	..	..	..	..	..	..	..	..	..
21	7	(1)	1	..	3	..	..	..	..	..	..	..	..	..	..
22	..	(1)	..	..	12	..	1	..	..	..	..	..	..	..	..
23	..	(1)	..	..	4	..	..	3	..	..	..	..	..	..	..
24	..	(4)	..	..	3	..	..	5	..	..	..	..	..	..	..
25	..	(5)	..	..	..	..	..	3	3	..	..	..	..	..	..
26	..	(7)	..	..	..	..	..	1	3	2	..	..	..	..	..
27	..	(2)	..	..	..	..	..	..	2	6	..	..	..	..	..
28	..	(2)	..	..	..	..	..	..	..	6	..	..	..	..	..
29	..	(2)	..	..	..	..	..	..	..	8	1	..	..	..	..
30	..	..	..	(1)	..	(1)	..	..	..	5	..	..	..	..	..
31	..	..	..	(6)	..	(2)	..	..	..	4	1	..	..	..	..
32	..	..	..	(1)	..	(4)	..	..	..	..	..	..	..	..	..
33	..	..	..	..	..	(1)	..	..	..	..	1	..	..	..	..
34	..	..	..	..	..	..	..	..	..	..	2	1	..	..	..
35	..	..	..	..	..	(3)	..	..	..	..	2	..	..	..	1
36	..	..	..	..	..	..	..	..	..	..	1	2	..	..	..
37	..	..	..	..	..	(1)	..	..	..	..	..	3	..	..	..
38	..	..	..	..	..	..	..	..	..	..	..	1	..	1	1
39	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
40	..	..	..	..	..	..	..	..	..	..	1	..	..	2	1
41	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
42	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..
43	..	..	..	..	..	..	..	..	..	..	..	..	..	1	3
44	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3
45	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3
46	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3
47	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4
48	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3
49	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2

specimens were collected at the same time and place? The agreement in the size of the scales is close. Other characters, however, point definitely to the identification of the variant fish as *C. commersonnii commersonnii.* As in the latter form, the short, blunt, and scarcely protruding snout is decidedly less elongate and prominent than in even the very small young of *C. catostomus,* recently transformed from the postlarval stage. The juvenile color pattern (little vermiculated, with three conspicuous dark blotches) is more like that of *commersonnii* than that of *catostomus.*

Furthermore, the dorsal rays (Table II) are typical of *Catostomus commersonnii commersonnii* and differ from those of *C. catostomus nannomyzon.* The average approximates that for the specimens of *C. commersonnii* from other localities in the Connecticut River system

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EXPLANATION OF SYMBOLS AND DATA IN TABLE III

The degree of completeness of the squamation is given in eight columns by the numbers 0 to 7, indicating stages of development as follows:

0 — No scales evident even on caudal peduncle.
1 — Scales evident only on mid-sides of tail region.
2 — Evident scales confined to a median strip, broadest toward caudal, but also developed just behind shoulder girdle.
3 — Squamation complete except on back before caudal peduncle.
4 — Squamation nearly complete except on back above mid-sides and before middle of dorsal fin.
5 — Squamation complete except over most of nape.
6 — Squamation complete except down middle of nape.
7 — Squamation complete.

No account was taken of the squamation of the lower parts anteriorly, and the scales were interpreted as present or absent by a surface examination with a high-powered binocular microscope, under a bright light.

The columns have from one to three sets of figures. These figures represent the number of specimens, of the given length, which were interpreted as being in the stage of development indicated at the head of the columns, as follows:

N — *Catostomus commersonnii commersonnii* from Nash Bog Pond. Normal specimens.

(A) — *Catostomus commersonnii commersonnii* from Nash Bog Pond. Abnormal specimens with retarded development (numbers in parentheses).

C — *Catostomus catostomus nannomyzon* from various localities in the Connecticut River system of New Hampshire. Several other young, more than 50 mm. long, were all in stage 7. The two young from Nash Bog Pond measured 40 mm. (stage 5) and 49 mm. (stage 7).

The size of the normal specimens of *Catostomus commersonnii* at the time of initial scale formation corresponds with the figure of "somewhat less than 22 millimeters," stated by Stewart (1926, p. 169).

in New Hampshire, and is somewhat higher than that for the normal specimens in the same collection. The agreement is close, however, when the abnormal specimens are compared with normal ones of like size (as indicated in Table II). The lower average number of dorsal rays in the smaller unmodified suckers of the August 25 collection may be another example of seasonal variation, by which the fish hatched in the warmer water show the fewer segments (see Hubbs, 1922, 1923, 1925, 1926a, 1934). That all fish listed in Table II represent young of the year seems obvious from the contributions of Bigelow (1924) and Hubbs and Creaser (1924).

The teratological suckers (Pl. I) were picked out by reason of the retention of larval features, indicative of abnormally delayed differentiation. The whole texture is soft and weak. Since the mouth is exceptionally oblique, as normally in very much smaller suckers (Stewart, 1926), the posterior angle of the mandible is much more conspicuous than usual. The body wall over the coelom is very flabby and transparent, largely because the superficial muscles are weakly developed; the heart and the ribs are clearly evident in external view. The pectoral fins retain a distinct trace of the larval pedunculation. The development of the squamation has been greatly retarded (Table III), as is further emphasized below.

The correctness of the separation of the abnormal specimens on the basis of these characters was fully confirmed when it was observed that the gill membranes in all the aberrant examples had remained free from the isthmus a strikingly longer time than in normal development (Table IV). This seems to be an unusual type of retention of a larval character, which I recall having otherwise seen only in a collection of *Margariscus margarita nachtriebi* from near the northern limit of its range (the specimens recorded by Cowan, 1939, p. 97); in this series most of the adults had the membranes free.

Postlarval habits as well as structures seem to have been retained by these teratological fish. Young suckers of their size (21 to 37 mm. in standard length) would be expected to have taken up a bottom habitat (Stewart, 1926, pp. 161 and 173, and personal observation). The collectors observed, however, that the abnormal fish were swimming about jerkily in short movements near the surface, therefore after the fashion of postlarval and very young juvenile suckers.

The important point in the present study is that some of the suckers from Nash Bog Pond in New Hampshire exhibit a greatly

TABLE IV

CHANGES, INDICATED BY FREQUENCIES, IN THE CHARACTER OF THE GILL MEMBRANES IN NORMAL AND IN ABNORMAL SUCKERS (*CATOSTOMUS COMMERSONNII COMMERSONNII*) FROM NASH BOG POND, NEW HAMPSHIRE

Standard length in mm.	Gill membranes free from isthmus or nearly so		Gill membranes partly attached to isthmus		Gill membranes wholly attached to isthmus	
	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal
14	3	..	..	..	..	..
15	5	..	..	..	..	..
16	14	..	8	..	..	..
17	5	..	16	..	..	..
18	..	..	23	..	..	..
19	..	..	17	..	19	..
20	..	..	3	..	18	..
21	..	1	..	..	10	..
22	..	1	..	..	12	..
23	..	1	..	..	7	..
24	..	4	..	..	8	..
25	..	5	..	..	6	..
26	..	7	..	..	6	..
27	..	2	..	..	8	..
28	..	2	..	..	6	..
29	..	2	..	..	8	..
30	..	1	..	1	5	..
31	..	3	..	4	4	1
32	..	2	..	2	..	1
33	..	..	..	..	..	1
34	..	..	..	..	1	..
35	..	1	..	..	..	2
36	..	..	..	..	2	..
37	..	..	..	..	3	1
38	..	..	..	..	2	..
39	..	..	..	..	..	..
40	..	..	..	..	2	..
41	..	..	..	..	..	..
42	..	..	..	..	..	..
43	..	..	..	..	1	..

delayed development of certain structures, including the scales (the reason seems relatively insignificant in the present interpretation), and that the scales show an increase of about 50 per cent in number. The explanation appears to be that the scale foci are laid down at approximately constant absolute distances from one another, whether the squamation develops early or late (Hubbs, 1927, pp. 93–94).

When scale formation is retarded while general growth is continued, there results a larger base on which the scales may develop. The number of scales which do form seems to be at least roughly proportionate to the area available.

In geographical as well as teratological variation there is considerable evidence that delayed lepidogenesis causes an increase in the number of scales. Thus in *Notropis cornutus* the final stages of scale formation, across the nape, are protracted toward the north, in correlation with the great increase northward in the number of predorsal scales (data in Hubbs, 1926b, pp. 38 and 46, and Hubbs and Brown, *in* Ortenburger and Hubbs, 1927, pp. 129–131).

It may now be regarded as reasonably well established that modifications in the rate of growth and of differentiation alter the characters of fishes, and play an important rôle in speciation.

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PLATE I

Teratological suckers from Nash Bog Pond, New Hampshire

The photograph, by F. W. Ouradnik, is used here by courtesy of the New Hampshire Fish and Game Department and Joseph R. Bailey

LEUCOCYTIC REACTION TO BACTERIAL INFECTION IN ANIMALS*

SISTER M. FRANCIS XAVIER O'REILLY

CERTAIN changes have been noted in the circulating polymorphonuclear leucocytes in men and the lower mammals during infections associated with the production of pus. Summarized briefly they are: (1) increased basophilia (acid reaction) of the cytoplasmic granules; (2) pycnosis of the nucleus (deep staining and clumping of the chromatin); (3) formation of basophilic nongranular areas (Döhle bodies) in the cytoplasm; and (4) vacuolization of the cytoplasm. When the bone marrow is unable to supply mature polymorphonuclear leucocytes in adequate numbers immature forms appear (the so-called "shift to the left").

In a series of experiments (O'Reilly, 1936) in which large doses of *Staphylococcus aureus* were injected into the rat an infectious state was produced and was accompanied by basophilia of the granules of the neutrophils, similar to that which is found in man during the course of a pyogenic infection.

To analyze the process of leucocytic behavior and immunity in man certain aspects of it have been studied in lower animals which are normally exposed to infecting media in their environment.

MATERIAL AND METHODS

In this analysis *S. aureus* (from a case of osteomyelitis) was injected into earthworms, crayfish, yellow perch, goldfish, mud puppies, frogs, garter snakes, turtles, pigeons, guinea pigs, rabbits, and mice. Mice were also inoculated with suspensions of lampblack and fibrin in order to compare the reactions of the leucocytes to an infecting organism and to a particulate matter (lampblack) and a foreign protein (fibrin).

The animals were kept under standard laboratory conditions. Films of blood in circulating body fluids stained by Wright's method

* Contribution from the Department of Zoölogy and the Thomas Henry Simpson Memorial Institute for Medical Research of the University of Michigan.

were studied before the animals were inoculated and at intervals of twenty-four hours after injection of measured amounts of the infecting organism. The types of leucocytes normally found in each species are listed in Tables I and II.

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EXPERIMENTAL ANIMALS

Earthworm (Lumbricus terrestris)

Twenty-four hours after the first injection of staphylococci into the coelom of an earthworm mononucleated cells of the circulating fluid were filled with these organisms (Pl. II, Fig. 1), and twenty-four

TABLE I

CELLS OF THE CIRCULATING FLUID OF TWO GROUPS OF INVERTEBRATES

The classification of the cells of the coelomic fluid of the earthworm was compiled from a comparative study of the normal cells of *Lumbricus terrestris* and from the description of them by Lim Boon Keng (1895); that for the cells of the crayfish was taken directly from Tait and Gunn (1918), after the normal cells and the description of them by Hardy (1892) and Meinertz (1902) had been studied.

	Earthworm	
Lymphocytes, spherical cells with deeply basophilic coarse granular nucleus	Monocytes (phagocytic, mononuclear), large hyaline cells; inner zone of cytoplasm contains fine eosinophilic granules; peripheral zone contains basophilic granules	Small spherical cells with eosinophilic granules
	Crayfish	
Explosive cells, spindle-shaped cells, and central nucleus	Hyaline thigmocytes (phagocytic); cytoplasm contains a large number of fine granules	Granular thigmocytes, variable in form; oval nucleus and cytoplasm filled with large granules

hours later the last few segments of the tail region were sloughed off spontaneously. Sections of these discarded terminal segments were filled with bacteria, which were distributed in the coelomic fluid, in the phagocytes, and in the chloragogue cells of that region. Each additional injection was followed by further loss of segments. Some of the animals shed as many as four times.

The regularity with which autotomy of the terminal segments containing phagocytes and bacteria followed injection led to the conclusion that in the earthworm foreign particles are ingested by phagocytic cells of the coelomic fluid and are carried to the posterior segments, which are then discarded. No cellular changes, such as digestion of the bacteria within the cell, are necessary to this animal in resisting infection.

Crayfish (Cambarus virilis)

After one day of infection with *S. aureus* the organisms were found in the hyaline thigmocytes of the circulating body fluid. Although these cells were studied in a variety of preparations, in films dried in air and stained with dilute methylene blue, in other films fixed in osmic acid vapor and stained with Wright's stain, in still other films stained with brilliant cresyl blue (vital stain), and in a hanging drop to which the infecting organism had been added, phagocytosis of the organisms was the only change observed. No evidence of the digestion of the bacteria contained in the cells or of any cell inclusions that resemble the granules of the neutrophils of man was visible. Two days after an injection an almost complete absence of phagocytes in the circulating fluid was noted. From this observation we can assume that the species possesses a peculiar mechanism for ridding itself of infecting organisms.

Yellow Perch (Perca flavescens) and Goldfish (Carassius auratus)

When staphylococci were first injected into the perch and goldfish the number of leucocytes increased. Continued injections (second, third, and fourth) on successive days maintained this increase in the number of white blood cells, which was also accompanied by phagocytosis (Pl. I, Fig. 2), pycnosis of the nucleus (Pl. I, Fig. 4c), and vacuolization in the cytoplasm. These pathological cells should be compared with the normal neutrophil (Pl. I, Fig. 1). During the course of infection the ingested bacteria underwent a

TABLE II

Leucocytes of Various Groups of Vertebrates

The descriptions of the leucocytes are taken from the work of other authors, as follows: for amphibians and mammals, from Scarborough (1930); for perch and goldfish, from Loewenthal (1928, 1930 a and b); for the pigeon, from Kennedy and Climenko (1928). Classification of the leucocytes in the garter snake and the turtle is the result of the author's study of the normal cells and of descriptions of the leucocytes in the literature of the subject.

Animals infected	Lymphocyte	Monocyte, mononuclear	Neutrophil	Eosinophil	Basophil
Perch....	Large and small forms	....	Contains fine neutral granules	....	....
Goldfish..	Normal	Normal	Nucleus may be simple or polymorph	Large cell with eccentric nucleus	....
Necturus and frog	Normal	....	Polymorphonuclear; polynuclear, but may be monolobed or bilobed; contains a few scattered fine metachromatic granules *	Normal	Normal
Snake....	Normal	Large cell with large eccentric nucleus	....	Large cell with lens-shaped polar nucleus, spherical or ellipsoidal red granules *	Mononuclear cell
Turtle ...	Normal	Large nongranular cell, spherical or oval	....	Lens-shaped polar nucleus, large red spherical or ellipsoidal granules *	Large and small varieties
Pigeon ...	Small, mononuclear	Large	....	Bilobed, with spherical or rod-shaped granules *	Spherical or reniform nucleus

* Phagocytic.

TABLE II (*Concluded*)

Animals infected	Lymphocyte	Monocyte, mononuclear	Neutrophil	Eosinophil	Basophil
Guinea pig	Resembles lymphocytes in man	Some cells contain Kurloff bodies	Pseudoeosinophil, 6–8-lobed nucleus, granules round, slightly basophilic *	Resembles eosinophil in man	Polymorphonuclear
Rabbit..	Resembles lymphocytes in man	Normal	Pseudoeosinophil or amphophile, polymorphonuclear, slight affinity for basic dyes	Polymorphonuclear	Polymorphonuclear
Mouse...	Normal	Normal	Polymorphonuclear	Polymorphonuclear	Polymorphonuclear

* Phagocytic.

gradual change: they increased in size (Pl. I, Fig. 3a), liquefied, completely filled the vacuoles that had formed around them, and became globular masses (Pl. II, Figs. 2–4) in the cytoplasm. As the digested material was absorbed by the cell the globules shrank (Pl. I, Fig. 4b) and changed in staining reaction from a red violet to blue, which gave them the appearance of Döhle bodies (Pl. I, Fig. 5d). The basic-staining areas are not similar to the basophilic granules seen in man during the course of an infectious disease, but they suggest a source of such basophilia.

Mud Puppy (*Necturus maculosus*) *and Frog* (*Rana pipiens*)

An increase in the number of leucocytes, phagocytosis, pycnosis of the nucleus, formation of vacuoles in the cytoplasm, and change in the staining reaction from a red violet to a blue were observed in the polymorphonuclear neutrophil (Pl. II, Fig. 6) and in a few mononuclear cells (Pl. II, Fig. 5) as the result of four successive daily injections into the mud puppy and frog. Vacuoles formed around the ingested staphylococci, which liquefied during digestion and created acid areas (Döhle bodies) in the cytoplasm. Nothing ap-

peared to suggest basophilia of the granules of the neutrophils as it appears during a pyogenic infection in man.

Garter Snake (Thamnophis sirtalis)

The first injection into the garter snake produced an increase in the number of leucocytes and a slight phagocytosis by the monocytes. Successive inoculations (two and occasionally a third) not only caused an increase of phagocytes, which included mononucleated cells and eosinophils with ellipsoidal granules, but also produced pycnotic nuclei and cytoplasmic vacuoles in the phagocytic cells. Changes in the staining reaction of the ingested bacteria from a red violet to a blue occurred as these organisms underwent digestion.

After the third dose of staphylococci a few inches of the tail of one of the snakes became swollen and discolored. Films made from the blood of this region showed many phagocytes and free bacteria (Pl. III, Fig. 1). The animal recovered without undergoing any further change.

Turtle (Emys blandingii)

Four injections administered daily into the coelom of the turtle increased the number of leucocytes and produced vacuoles in the cytoplasm and an almost spherical swelling of the ellipsoidal granules of the eosinophils. Some of these eosinophils were broken while the films were being made, and it was in these cell fragments that staphylococci were observed well embedded near the pycnotic nucleus. Phagocytes were not numerous in the blood films, but there was an increase in the number of the eosinophils with ellipsoidal granules, in the fragments of which were phagocytosed bacteria.

Pigeon

The first injection into the pigeon produced a definite leucocytosis which, unlike the condition in other groups, persisted for several days after successive inoculations (five) had been discontinued. In the pigeon the eosinophil with rod-shaped granules is the phagocytic cell, and during the time of infection these granules became so swollen that they gave the cell a "plump" appearance (Pl. III, Fig. 2). The change in shape was accompanied by vacuolization of the cytoplasm and changes in staining reaction from a lighter to a darker blue. The digested material in the swollen granule never quite filled the vacuole as it did in other animals.

Guinea Pig

One injection produced an increase in the number of leucocytes. No further change was apparent after a second injection. Basophilia of some of the granules of the pseudoeosinophils (Pl. III, Fig. 3) followed the third injection, and basophilia of a greater number of granules ensued after the fourth. This basophilia of the granules of the pseudoeosinophils of the guinea pig is similar to that of the polymorphonuclear neutrophils appearing in man during the course of an infectious disease.

Two guinea pigs died after receiving extra large doses of unusually virulent *S. aureus*. Blood taken from their hearts showed all the pseudoeosinophils filled with staphylococci.

Rabbit

Three subcutaneous injections were given on alternate days to the rabbits. The infection so induced was accompanied by basophilia of the granules of the pseudoeosinophils (Pl. III, Fig. 6), similar to that found in human neutrophils during the course of an infectious disease.

Mouse (Mus musculus)

Young mice of C57 (black) and dba (dilute brown) varieties from the Roscoe B. Jackson Memorial Laboratory, Bar Harbor, Maine, were used in this experiment.

In the normal neutrophils of the black mice no granules occur. After two days of infection a few fine slightly basophilic granules appeared in the cytoplasm of the neutrophils. A third day of infection increased the number of basophilic granules of these cells (Pl. III, Fig. 5). No further change could be caused.

In the dilute brown variety of mice two injections produced basophilia of the granules of some of the neutrophils. Basophilia of the granules of a greater number of the neutrophils followed the third injection (Pl. III, Fig. 4). In both varieties of mice this basophilia was similar to that observed in the rat in a series of experiments by the writer (O'Reilly, 1936) and to that found in man during a bacterial infection.

Two groups of mice were inoculated with a sterile suspension of lampblack in saline: one group received three injections at weekly intervals; the other group, the same number but on successive days.

Twenty-four hours after the first injection deposits of this substance were present in the neutrophils (Pl. I, Fig. 6). Similar deposits were observed several days after the inoculations had been discontinued.

A sterile suspension of powdered fibrin (one per cent in physiological salt solution) was also used to inoculate two groups of mice. Two died a few hours after the first inoculation: one a few hours after the second inoculation of fibrin; the other shortly after a third inoculation of the substance. In the blood films made after the injections only an occasional neutrophil was found. Neither basophilia of the granules nor any change in the cytoplasm of the few neutrophils remaining in the circulation was evident.

DISCUSSION

Results of this investigation of the reaction of leucocytes in a variety of animals to the presence of an infecting organism indicate that in each class of animals studied a particular reaction or set of reactions is induced to protect the animal against bacteria and their metabolic products. In man reaction to infection can be noted by visible changes in the neutrophils. Normal neutrophilic granules become more acid (basophilia of the granules), acid areas (Döhle bodies) appear in the cytoplasm, vacuolization occurs, and the nucleus becomes more compact (pycnotic).

In the animals studied many of these changes, such as the presence of vacuoles and acid areas which resemble Döhle bodies in the cytoplasm and pycnosis, were duplicated. In the lower vertebrates these reactions were preceded by phagocytosis. Basophilia of the granules was limited to mammals, whereas in the invertebrates the cells of the circulating body fluids were actively phagocytic, but presented none of the changes noted in the vertebrates. From these observations we may conclude that the visible mechanisms for resisting the action of infecting organisms in the blood or circulating fluid of the groups of animals under investigation fall into three distinct categories: (1) phagocytosis and excretion; (2) phagocytosis and digestion; and (3) basophilia of the granules of the polymorphonuclear neutrophils or their homologues, the pseudoeosinophils.

Cells of the circulating body fluids of the earthworm defend themselves against bacteria by phagocytosis and autotomy. Cuénot (1897) and Willem and Minne (1899; cited by Lison, 1928) acknowl-

edge the existence of an excretory function of the "amoebocytes" of *Lumbricus* and describe the passage of cells containing particles of injected dye from the coelom into the lumen of the intestine, where they are excreted with the feces. Lison (1928), commenting on the method by which the animal rids itself of tubercle bacilli, says that the organisms are removed by phagocytosis and excretion, and Keilin (1925) finds that, when this animal is infected with parasites, it carries the infecting organisms to the posterior end of the body, where the last few parasite-laden segments are removed by autotomy.

The present study likewise ascribes an excretory rôle to the mononucleated cells, since they engulf the staphylococci that have been injected into the coelom and carry them to the posterior end of the body, where the segments containing them drop off.

The hyaline thigmocytes of the crayfish were definitely phagocytic, but there was no evidence of digestion of the engulfed bacteria; nor were there any cell inclusions that resembled in any way the granules of the neutrophils of man. Although it may be assumed from these observations that the organisms were excreted by the hyaline thigmocytes which contained bacteria after injection and which were definitely phagocytic in a hanging drop, yet these phagocytes never appeared in great numbers in the stained films, and, as a rule, had almost entirely disappeared forty-eight hours after injection. Helen Pixell-Goodrich (1929), in describing an infectious disease of Gammarus, another crustacean, says it is sometimes cured by phagocytosis and autotomy. Though removal of infecting organisms by autotomy is not proved in this study, some evidence has been accumulated which indicates that it occurs.

A second mechanism, that of engulfing and digesting the invading organism, was observed in the lower vertebrates. Leucocytes of the fish, amphibians, and snakes ingested the organisms, formed vacuoles around them, appeared to pour secretions into the vacuoles which digested the bacteria, and then absorbed the soluble material. As digestion and absorption proceeded, the reaction of the digested material changed, so that definitely acid areas which resembled Döhle bodies appeared in the cytoplasm.

An outstanding difference noted in the leucocytes of the snake and in those of the fish and amphibians studied is the inclusion of a granular cell among the phagocytes of the former. Although granules

were present in these cells, there was no suggestion of basophilia of these granules like that seen in man during pyogenic infection.

The ellipsoidal or rod-shaped granules of the eosinophils of the snake, turtle, and pigeon became swollen and assumed an almost spherical shape after injection. This change followed phagocytosis and was accompanied by vacuolization in the cytoplasm, particularly around the ingested organisms, and by digestion and absorption of the engulfed bacteria. The organisms changed in their staining reaction from a red violet to a blue, except in the pigeon, in which the change was from a lighter to a darker blue. As the pigeons recovered from infection the rod-shaped eosinophilic granules that had become swollen lost their spherical shape and became normal in appearance.

Mammals included in this experiment, that is, guinea pigs, rabbits, and mice, responded to injection by a basophilia of the granules of the neutrophils which was similar to the basophilia found in the human neutrophil during the course of an infectious disease. This group showed no evidence, however, of the phagocytosis engendered among the lower vertebrates.

Infection in man is known to produce changes in the nucleus and cytoplasm, and basophilia of the granules of the neutrophils. These same changes were observed in the phagocytic cell of the leucocytes of the vertebrates investigated in this report, although in each group below the mammals they were accompanied by visible phagocytosis. Furthermore, as the engulfed organisms underwent digestion, changes occurred in the staining reaction of the ingested bacteria in the vertebrates but not in the invertebrates. Thus we may conclude that the infecting organism was removed from the invertebrates studied by means other than digestion.

Early in this investigation it became apparent that, if ten or more days were allowed to elapse between the first and the second inoculations, subsequent doses had no visible effect. During the intervening days the animal built up an immunity against the infecting organism. In order to obtain reactions in which the bacteria or their toxins caused definite changes in the cells it was necessary to repeat the inoculations on at least three successive days. That the changes so induced resulted from the injections of *S. aureus* is obvious since the injections of neither lampblack, a particulate matter, nor fibrin, a foreign protein, effected any discernible alteration in the staining properties of the leucocytes.

During the course of the disease some of the infected animals showed signs of it in their appearance and behavior. This was true especially of the snakes, pigeons, rabbits, and mice. Loss of resistance to handling, a drooping appearance, and refusal to eat were common symptoms of infection among the several groups. These clinical changes suggest that the reactions were caused by infection rather than by the injection of inactive particles.

CONCLUSIONS

1. Large nongranular mononucleated cells of the earthworm engulf infecting organisms and carry them to the posterior end of the body, the last few bacteria-laden segments of which are lost by autotomy.
2. Hyaline thigmocytes of the crayfish phagocytose the infecting organisms and then remove them from the circulating body fluid.
3. Phagocytic leucocytes of perch, goldfish, mud puppy, frog, and snake (monocyte) engulf and digest the injected *S. aureus*, after which changes of the nucleus (pycnosis) and the cytoplasm (vacuolization) are observed. Acid areas resembling Döhle bodies appear in the cytoplasm during the absorption of the digested material.
4. Eosinophils with ellipsoidal or rod-shaped granules engulf the *S. aureus* injected into the snake, turtle, and pigeon. Subsequent changes observed are pycnosis in the nucleus and vacuolization in the cytoplasm. In the snake the eosinophils constitute a second form of phagocyte.
5. Basophilia of the granules in the pseudoeosinophils of the guinea pig and the rabbit and in the neutrophils of the mouse appear after three days of infection with *S. aureus*.

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EXPLANATION OF PLATE I

FIG. 1. Normal neutrophil of perch

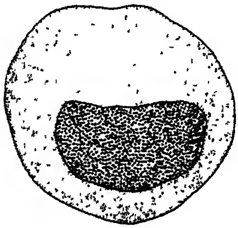
FIG. 2. Neutrophil of perch, showing phagocytosed bacteria and vacuoles in the cytoplasm

FIG. 3. Neutrophil of perch, showing enlargement of the staphylococci in the vacuole (*a*)

FIG. 4. Neutrophil of perch, showing globules in the cytoplasm (*b*) and pycnosis of the nucleus (*c*)

FIG. 5. Neutrophil of perch, showing a few small globules in the cytoplasm resembling Döhle bodies (*d*)

FIG. 6. Neutrophil of mouse, showing phagocytosed lampblack



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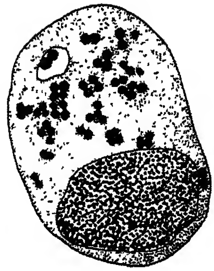

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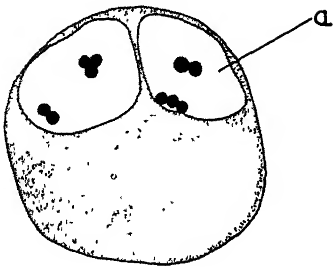

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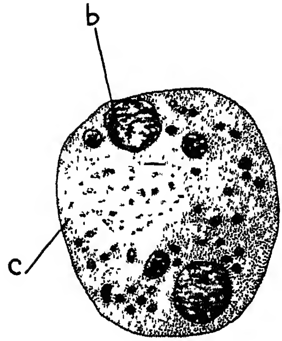

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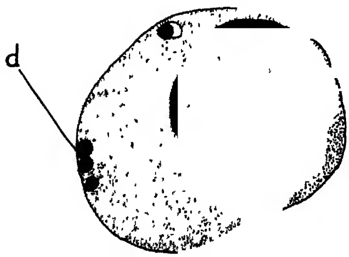

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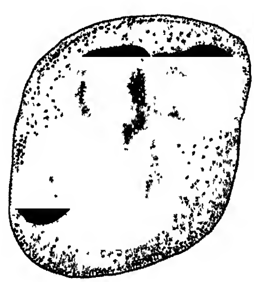

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E. Herbold, del.

EXPLANATION OF PLATE II

The explanations apply to the white blood cells only.

FIG. 1. Monocyte of earthworm containing phagocytosed bacteria. Twenty-four hours after first inoculation

FIG. 2. Neutrophil of goldfish containing phagocytosed bacteria and showing early globule formation. Twenty-four hours after third inoculation

FIG. 3. Neutrophil of perch containing phagocytosed bacteria and showing early globule formation. Twenty-four hours after third inoculation

FIG. 4. Neutrophil of perch showing globule formation. Forty-eight hours after fourth inoculation

FIG. 5. Mononuclear leucocyte of *Necturus* containing phagocytosed bacteria. Twenty-four hours after third inoculation

FIG. 6. Polymorphonuclear neutrophil of frog containing phagocytosed bacteria. Twenty-four hours after first inoculation

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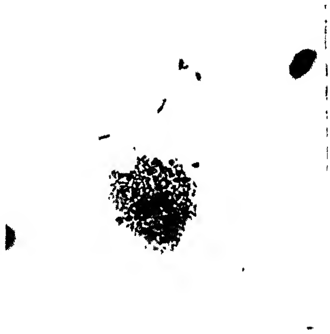

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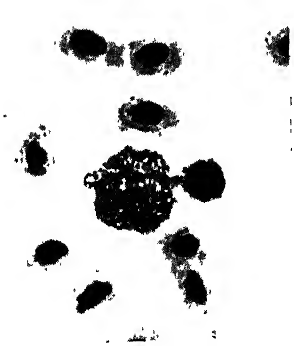

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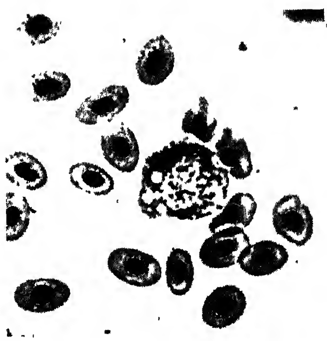

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EXPLANATION OF PLATE III

The explanations apply to the white blood cells only.

Fig. 1. Monocytes of snake. Blood taken from swollen tip of the tail after third inoculation. Note the appearance of the leucocytes and the number of bacteria

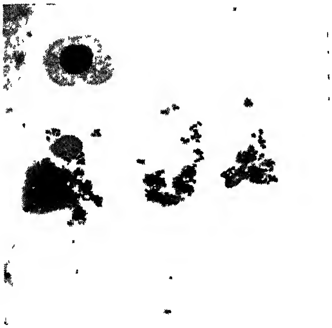
Fig. 2. Eosinophils containing rod-shaped granules of pigeon. Forty-eight hours after fourth inoculation

Fig. 3. Pseudoeosinophil (lower left and upper right) of guinea pig, showing fine basophilic granules. Twenty-four hours after third inoculation

Fig. 4. Polymorphonuclear neutrophils of brown mouse. Twenty-four hours after third inoculation

Fig. 5. Polymorphonuclear neutrophils of black mouse. Twenty-four hours after third inoculation

Fig. 6. Pseudoeosinophils of rabbit showing basophilic granules. Twenty-four hours after third inoculation



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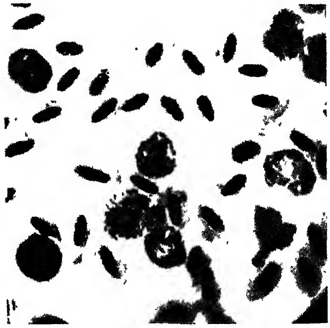

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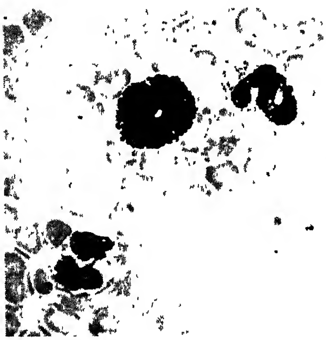

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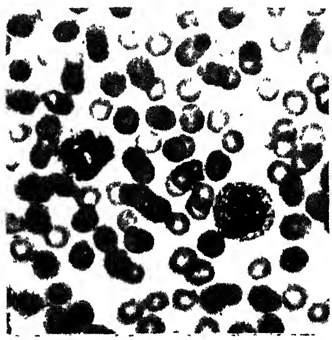

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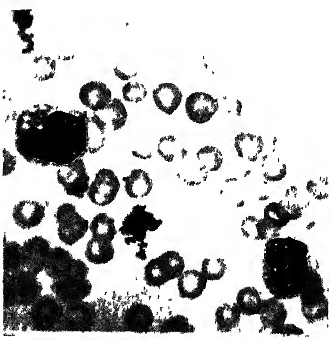

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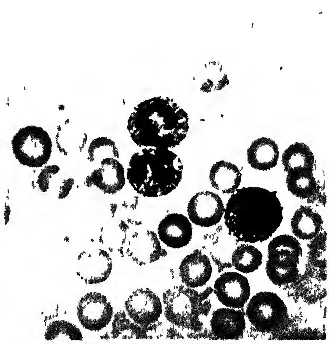

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THE DISPERSAL OF WILD DUCKS FROM THE W. K. KELLOGG BIRD SANCTUARY, NEAR BATTLE CREEK, MICHIGAN

MILES D. PIRNIE

IN 1931 the author reported on the fall migration of the black duck from northern Michigan as indicated by available records of recaptures of wild individuals trapped and leg-banded at the Munuscong (Munuskong) State Waterfowl Refuge bordering St. Mary's River, approximately 20 miles south of Sault Ste Marie.[1] Opportunity for a similar study in southern Michigan came in 1931, when the author took charge of the W. K. Kellogg Bird Sanctuary of Michigan State College. This sanctuary is located at Wintergreen Lake in northeastern Kalamazoo County, about 50 miles east of Lake Michigan and the same distance north of the Indiana line. It is 250 miles south of the Munuscong Refuge and well within the Mississippi flyway of Lincoln.[2] In this discussion the designation "station area" includes the southwestern corner of the state, twenty counties in all, bordered roughly by a line from Muskegon to Alma, thence south through Lansing and Jackson to the Indiana boundary.

Table I shows the numbers and the species of ducks most commonly trapped and leg-banded at Wintergreen Lake between July, 1931, and December, 1939. They were captured in traps of poultry netting baited with corn and wheat at funnel-shaped entrances. Mallards were taken chiefly at marshy ponds; "blacks" were secured more readily at lake-shore traps. The last column of Table I gives the total and the percentage of recaptures or "returns" for each species up to February, 1940.

By January 31, 1940, 727 bands had been reported, indicating

[1] Pirnie, Miles D., "Fall Migration of the Black Duck from Northern Michigan," *Pap. Mich. Acad. Sci., Arts, and Letters*, 15 (1931): 485–490. 1932.

[2] Lincoln, Frederick C., *The Waterfowl Flyways of North America.* U. S. Dept. Agric., Circ. 343 (1935).

TABLE I

SUMMARY OF WATERFOWL BANDED AT THE W. K. KELLOGG BIRD SANCTUARY, 1931–39, AND RECAPTURES REPORTED UP TO FEBRUARY, 1940

Species	Number banded										Reported recaptures
	1931	1932	1933	1934	1935	1936	1937	1938	1939	Totals	
Black duck (*Anas rubripes*)	1,194	414	232	129	105	303	630	786	320	4,113	516 (12.5%)
Mallard (*Anas platyrhynchos*)	445	142	41	53	34	99	256	373	303	1,746	182 (10.4%)
Redhead (*Nyroca americana*)	17	33	3	1	..	23	9	3	2	91	6 (6.6%)
Pintail (*Anas acuta*)	64	7	..	..	..	..	1	1	7	80	8 (10.0%)
Baldpate (*Mareca americana*)	58	..	..	1	..	7	..	..	..	66	15 (22.7%)
Totals	1,778	596	276	184	139	432	896	1,163	632	6,096	727 (12.0%, av.)

the recapture of over 12 per cent of the 6,096 ducks that were banded between 1931 and 1939. Over 95 per cent of these records came from hunters who shot the birds during the hunting seasons, between September and late December. Spring recoveries were obtained in considerable numbers only for the blacks trapped and shot in Ontario.

Table II summarizes the recoveries of the black duck and the mallard, the only species which were trapped and banded in numbers for nine consecutive years at Wintergreen Lake. In this table the

TABLE II

SUMMARY OF BLACK DUCK AND MALLARD RECOVERIES UP TO FEBRUARY, 1940

Locality	Black duck		Mallard		Totals
	First year	Later years	First year	Later years	
Michigan:					
Station area*..	161	150	38	36	385
Outstation area	13	33	2	4	52
Other states.....	35	74	17	54	180
Canada.........	..	50	..	31	81
Totals reported	209	307	57	125	698

* The twenty counties of southwestern Michigan.

Michigan totals are segregated from those for other states and Canada. Birds taken within a few weeks or months after banding are listed separately from those captured after a lapse of a year or more.

BLACK DUCKS

Of 4,113 black ducks 516, or 12.5 per cent, have been reported. Michigan recoveries total 357, or almost 70 per cent. Only 46 were shot at a considerable distance from the station area; and four counties (Barry, Allegan, Kalamazoo, and Calhoun) reported 279 bands, more than 75 per cent of the Michigan total! This is not surprising since these banded birds were obviously more concentrated there than elsewhere, and since the many lakes, ponds, and streams of southwestern Michigan are very heavily hunted.

The first-year Michigan recoveries outside the station area include 13 birds which went from 100 to 200 miles north or east a few weeks after they had been banded. These were shot in the northern part of the Lower Peninsula and on Lake St. Clair and Saginaw Bay. Four were killed in central Wisconsin, approximately 200 miles northwest of the point of banding. Examination of Figure 1 and Table III shows first-season recoveries as far away as Missouri, Louisiana, Florida, South Carolina, and Maryland, with a concentration in the Ohio, Michigan, and northern Indiana region.

Later Michigan recoveries in the station area totaled 150 as against 161 the first season; but recaptures elsewhere in Michigan in later years were 33, or more than twice the 13 first-year captures. First-year recoveries in other states totaled 35 as against 74 taken later. Although no banded black ducks were shot in Canada in the season of banding, 50 were eventually reported, of which 32 were from points north of Lake Huron and Lake Superior. Three were killed near Churchill in Manitoba, on the west side of Hudson Bay, and eight on or near James Bay, an average distance of 800 miles north of the banding station. Especially significant are the 22 spring and early-summer records of black ducks far north in Ontario at nesting time. The distribution of the Canadian recaptures is shown by provinces in Table III.

Later occurrences in the United States differ from the first-year spread chiefly in the greater numbers reported from Wisconsin and Minnesota and in the long-distance wandering indicated by the Idaho and Alaska birds.

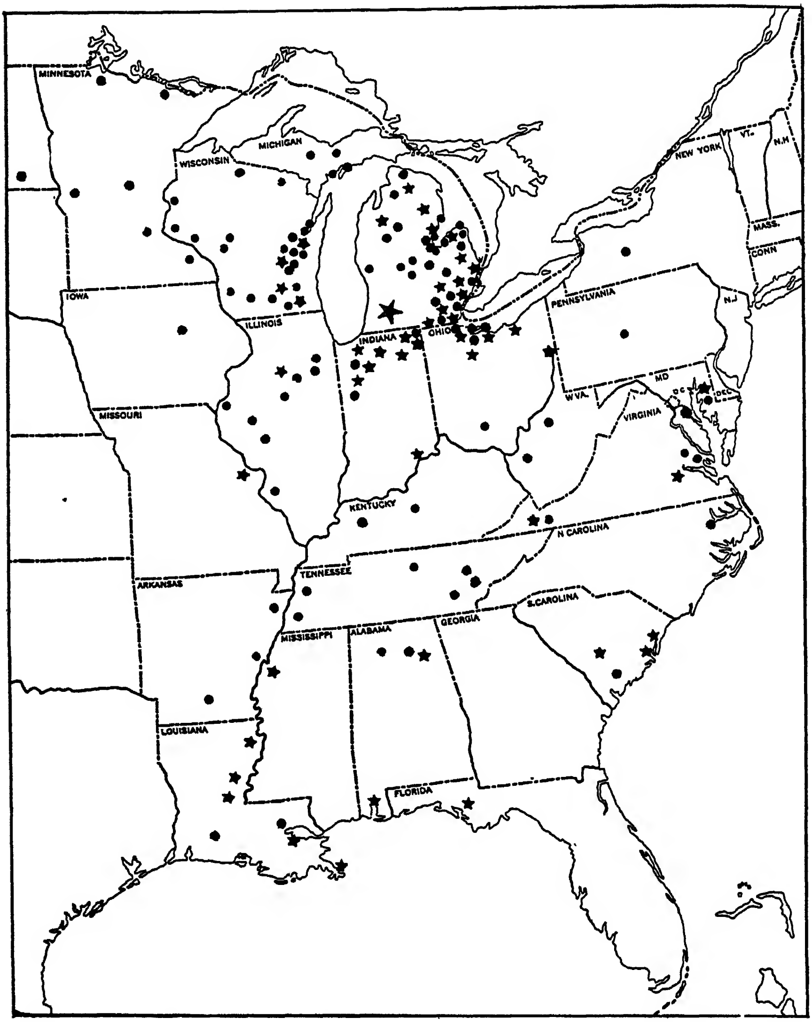

FIG. 1. Black duck recoveries in the United States, not including one in Idaho and 311 recaptured in the station area at Wintergreen Lake (★)

★ Recaptured same year as banded

● Recaptured after one or more years

TABLE III

Distribution of Black Duck and Mallard Recoveries up to February, 1940

Province or state	Black duck		Mallard		Totals
	First year	Later years	First year	Later years	
Alaska	..	1	..	..	1
Alberta	..	..	..	2	2
Saskatchewan	..	..	..	2	2
Manitoba	..	6	..	15	21
Ontario	..	42	..	11	53
Quebec	..	2	..	1	3
New York	..	1	..	1	2
Pennsylvania	..	1	..	..	1
Michigan	174	183	40	40	437
Wisconsin	4	21	2	16	43
Minnesota	..	6	1	12	19
North Dakota	..	1	..	..	1
South Dakota	..	..	..	2	2
Idaho	..	1	..	..	1
Iowa	..	1	..	..	1
Missouri	1	..	..	..	1
Illinois	1	9	1	11	22
Indiana	8	3	2	1	14
Ohio	5	5	1	6	17
West Virginia	..	2	..	..	2
Maryland	2	1	..	..	3
Virginia	2	3	..	..	5
Kentucky	..	2	..	..	2
Tennessee	..	6	4	2	12
Arkansas	..	3	1	1	5
Texas	..	..	..	1	1
Louisiana	5	2	1	..	8
Mississippi	1	..	1	1	3
Alabama	2	2	1	..	5
North Carolina	..	1	..	..	1
South Carolina	3	2	2	..	7
Florida	1	..	..	..	1
Totals	209	307	57	125	698 (12%, av.)

MALLARDS

Of 1,746 mallards leg-banded from 1931 through 1939, 182, or 10.4 per cent, had been reported prior to February, 1940. Figure 2 shows the location of all recoveries in the United States, and Table II contrasts early and later recoveries. Table III gives total returns by states and provinces. The Michigan total for later years equals that of the first year, but returns from other states were more than trebled. Of the 182 recoveries Canada turned in 31, or 17 per cent, which is almost double the 9 per cent of black duck returns (only 50 out of 516).

The dispersal of mallards soon after banding is shown by the small stars in Figure 2. Attention is called to the two in Wisconsin and the one in southern Minnesota northwest of the Wintergreen Lake banding station. The Minnesota bird had traveled at least 400 miles to the west and north in eight days! Eastern drift is shown by the two birds shot in the Detroit area and the one at Toledo. Very strangely, of the 15 reported south of Kentucky 10 were first-year recoveries and only five were of later periods. (In later years the total for the United States, excluding Michigan, trebled the first-year kill.) Subsequent travel through Wisconsin, Minnesota, and the prairie provinces is shown in Figure 2 and Table III. Significant are the 15 Manitoba recoveries and the 11 Ontario ones. The two Saskatchewan records are the farthest west. Several birds were shot north of Lake Winnipeg in Manitoba, also two at the south shore of Hudson Bay and one near Montreal. All four of the later recoveries in Michigan away from the station area were from the marshes of Saginaw Bay. (In contrast, many of the later recoveries of black ducks were from interior waters as well as from Saginaw Bay, Lake St. Clair, and the Erie marshes.)

OTHER SPECIES

Of 91 redheads banded six have been reported in later years, all on an east–west axis, as follows: South Dakota, 1; Detroit area, 1; southern Ontario, 2; and Maryland, 2.

Eighty pintails were leg-banded, as indicated in Table I. The eight recoveries were widely scattered. There were two first-year kills near the station; for later periods the recoveries are: Wisconsin, 2; Kentucky, 1; Tennessee, 1; North Carolina, 1; South Carolina, 1.

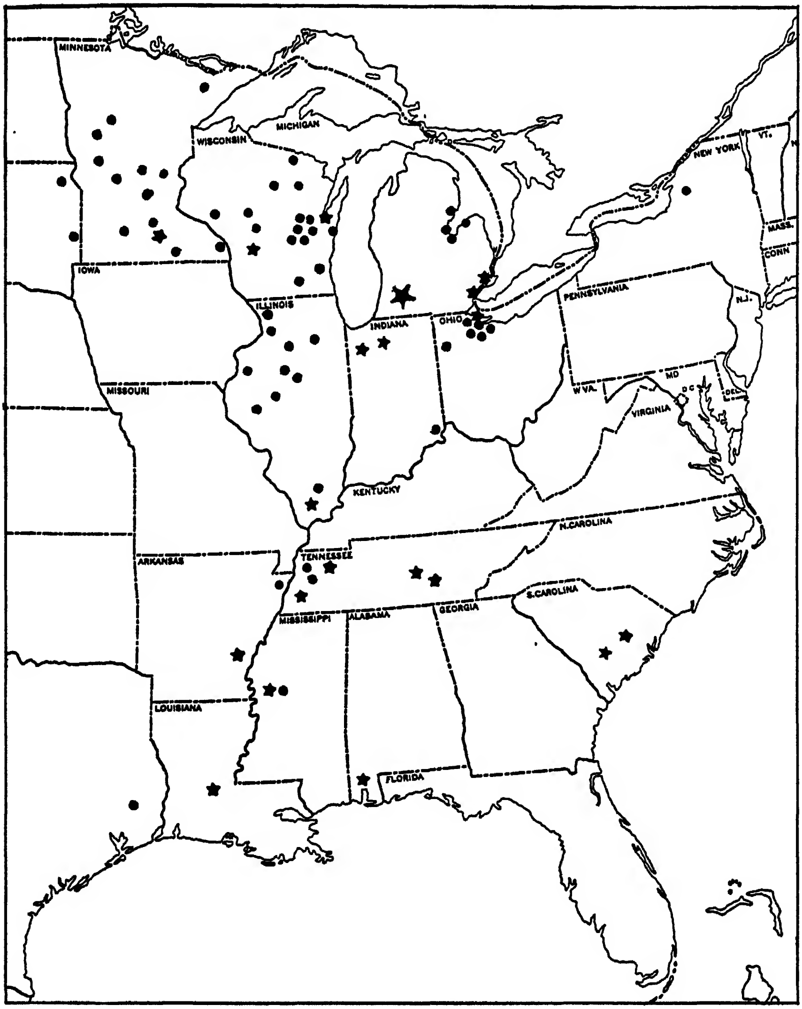

FIG. 2. Mallard recoveries in the United States, not including 84 recaptures in the station area at Wintergreen Lake (★)

★ Recaptured same year as banded

● Recaptured after one or more years

Again a southeast drift across the central and southeastern states is suggested.

The 66 baldpates gave a total of 15 returns. First-season dispersal includes one reported in southern Wisconsin and one from Long Island, New York. Among later recoveries are those from: Lake Athabaska in Alberta, 2; Nebraska, 1; Wisconsin, 2; Michigan, 5; Virginia, 2; and North Carolina, 1. Again the diagonal flight is indicated — southeast and northwest. The 23 per cent kill reported strongly suggests the importance of shooting as a mortality factor.

SUMMARY

1. In their fall dispersal from southern Michigan some black ducks and mallards travel as far as 200 or more miles west, north, or east. A mallard was shot in southern Minnesota on October 22, 1932, only eight days after it had been banded at Wintergreen Lake. Two mallards and four black ducks were killed in Wisconsin and numbers of black ducks have been taken in northern Michigan counties the same fall as they were banded.

2. The southward drift of black ducks and mallards from southern Michigan resembles the pattern of black duck dispersal from northern Michigan, but mallards seem to scatter less widely over the southeast. Recoveries in Louisiana are quite frequent, if the gradual dilution of banded individuals among unbanded birds is taken into consideration.

3. The black ducks marked at Wintergreen Lake scatter widely over the Mississippi and Atlantic flyways, from northern Manitoba and Ontario south to Louisiana and South Carolina, but apparently avoid the northeastern states.

4. Recovery of 22 banded black ducks in northern Ontario in spring and early summer strongly indicates that this is the nesting home of many of the individuals leg-banded in this study.

5. A black duck shot in Idaho and another on the west coast of Alaska confirm the western extension of range credited to this species by numerous observers in recent years.

6. The mallards were reported chiefly from the Mississippi flyway, migrating from the prairie provinces down across Minnesota, Wisconsin, and Illinois to Louisiana by a gradually narrowing route. Few seem to reach the Atlantic coast. The 30 captures at points in Canada north and west of Michigan indicate Canadian nesting by

many of the mallards which were leg-banded in fall at Wintergreen Lake.

7. The very limited banding of baldpates and redheads has yielded some evidence of migration along a northwest–southeast diagonal route. The pintail returns indicate a more general scattering over the south and east.

W. K. Kellogg Bird Sanctuary
Battle Creek, Michigan

THE INHERITANCE OF A COLOR VARIATION IN THE CODLING MOTH, *CARPOCAPSA POMONELLA* LINNÉ

PAUL L. RICE

INTRODUCTION

AN EXAMINATION of the publications in the field of economic entomology during the past fifteen years will probably show that more space has been given to the discussion of the codling moth, *Carpocapsa pomonella* Linné, than to any other insect. Most of these numerous articles and bulletins have to do with either the biology or the control of this troublesome orchard pest. The present discussion is a less serious one. The author has concerned himself with a study of the genetical behavior of certain codling moths that show a definite color variation.

While occupied with entomological work for the Idaho Agricultural Experiment Station the writer noticed that some specimens of the codling moth were distinctly different in their coloration from the common type. This color variety had been observed by entomologists for a number of years. The problem of investigating the possible genetical relationship of these two strains was undertaken. The work was begun in 1927 and was continued intermittently, as a minor project, through 1934. At that time it was hoped that further experiments could be carried on to confirm some of the results obtained, but a change of residence prevented this. Although the results reported below are not so full as might be desired, it is felt that they are sufficiently conclusive to warrant their publication.

DISTRIBUTION AND FREQUENCY OF OCCURRENCE OF LIGHT MOTHS

The usual color of the codling moth is dark gray, with spots of a bronze shade, whereas the light strain is tan, spotted with brown. Observations made in southwestern Idaho in 1934 indicated that approximately six per cent of the population were of the light-colored

variety. This estimate was based upon counts of 9,017 moths, of which 529 were found to be tan. An earlier sample, taken in a different community within the same general region, showed that the percentage of light moths there was twice as high. So far as it was possible to determine, the light variety occurs in greater frequency in southwestern Idaho than elsewhere. In northern Idaho the light specimens are much scarcer, and in central Washington they appear so infrequently that they are almost regarded as an oddity by the entomologists. While the writer was in Delaware he examined several thousand moths, but saw none of the light variety. Observations in other states in the East and in the Middle West, together with information gained from entomologists living in these regions, have led to the belief that the light strain is unknown there.

PROCEDURE AND METHODS

Initial experiments showed that, when light moths crossed with light, the offspring were all of the parental color, but a small percentage of light moths appeared among the progeny of dark parents. These observations indicated that the color variation had a genetical significance, and hence it could not be accounted for by variations in environmental conditions. After this, further experimental crosses were carried out, light being mated with light, dark with dark, and dark with light. Later, when the results had justified the tentative assumption that dark was the dominant characteristic and light the recessive, heterozygous dark moths were obtained by choosing the dark progeny of light × dark crosses. Matings were produced among these supposedly heterozygous dark moths and also between the light and the heterozygous dark strains.

The rearing methods used were similar to those employed by a number of workers who have investigated the life history of the codling moth. Adults were confined in battery-jar cages and were allowed to oviposit upon apple leaves. Apples were provided for the larvae to feed upon. Mature larvae were induced to enter corrugated paper strips, where they spun their cocoons and passed through the pupal stage. The colors of the emerging adults were recorded, and they were segregated for additional breeding experiments. Special care was taken in handling all stages in order to prevent contamination of the cages by strains of the insect other than the ones desired.

When a single pair of moths was confined separately within a cage, poor mating results were obtained. Hence it was necessary to place several pairs together in making crosses.

RESULTS OF THE MATINGS

From the matings in which dark moths, selected at random from the population, were used, 146 progeny were reared to maturity. Of these, 134 were dark and 12 were light. One hundred and fifty-eight moths were obtained from the crosses of light × light. All but one were light in color. Even though great care was taken to prevent mixing of the stock in the various cages, there was still a possibility that a small larva from an unknown strain might have gained entrance to one of the feeding cages containing the larvae of light moths. This would account for the appearance of the dark moth.

One hundred and forty-three offspring were reared from parents assumed to be heterozygous dark. Of this number 31, or 22 per cent, were light.

Only one backcross, involving the mating of heterozygous dark moths with light moths, was made. From this cross 30 offspring were obtained, 60 per cent of which were dark and 40 per cent light.

DISCUSSION AND CONCLUSIONS

Since dark gray is the common coloration of the codling moth and since the tan variety is apparently limited in its distribution to the Pacific Northwest, it is logical to assume that the light strain has arisen as a mutation from the dark.

Experimental evidence indicates that a single factor is involved in color determination and that the dark characteristic is dominant over the light. The facts that a small percentage of light moths appeared among the offspring of dark × dark matings and that light moths produced light offspring only (the one discrepancy noted, in view of other evidence, being accounted for as an error in technique) support this view. The progeny of crosses in which heterozygous individuals were mated among themselves, where a proportion of 25 per cent light to 75 per cent dark would be expected theoretically, showed a color distribution of 22 per cent light to 78 per cent dark. Since the total offspring reared from such crosses was only 143, these results would be considered reasonably close to the theoretical values. In the backcross, in which the expected F_1 results would be 50 per

cent light to 50 per cent dark, the observed results were 40 per cent light to 60 per cent dark. Again the variation from the expected ratios can be explained on the basis of the small population dealt with. These data, when considered together, give strong support to the belief that the factors involved are a simple dominant and a recessive.

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THE MOVEMENTS OF MARKED FISH IN DOUGLAS LAKE, MICHIGAN *

IMMANUEL A. RODEHEFFER

THIS study of the movements of fish in Douglas Lake, Cheboygan County, Michigan, is the outgrowth of other investigations carried on in the lake by the writer during two previous summers. In the summer of 1937 ten experimental brush shelters were installed and studied at Grapevine Point in Douglas Lake (see map, Fig. 1) to determine to what extent fish of various species and sizes would use such devices as warm weather habitats (Rodeheffer, 1939). In July and August of 1938 the same shelters were kept under continued observation to discover if the same species and sizes of fish would again be found using the structures and to obtain further evidence on the differences in the fish population utilizing the artificial covers by day and by night (Rodeheffer, 1940). To ascertain how rapidly and to what extent shelters would become repopulated if all fish were removed, four more shelters were built and placed in North Fishtail Bay in July, 1938.

These investigations during the summer seasons of 1937 and 1938 in the eastern end of Douglas Lake showed that:

1. If fish shelters are installed on a practically barren shoal, such devices will attract fish (Rodeheffer, 1939).
2. There is a great diurnal fluctuation of fish populations within a given area (Rodeheffer, 1940).
3. As fish are removed from a part of a lake where protection is offered, others will repopulate such regions (Rodeheffer, 1940).

Primarily in connection with the studies of the utilization of the brush shelters by fish many game fish were marked at Grapevine Point in the summer months of 1937 and 1938 and at Hook Point,

* Contribution from the Institute for Fisheries Research of the Michigan Department of Conservation and the Biological Station of the University of Michigan.

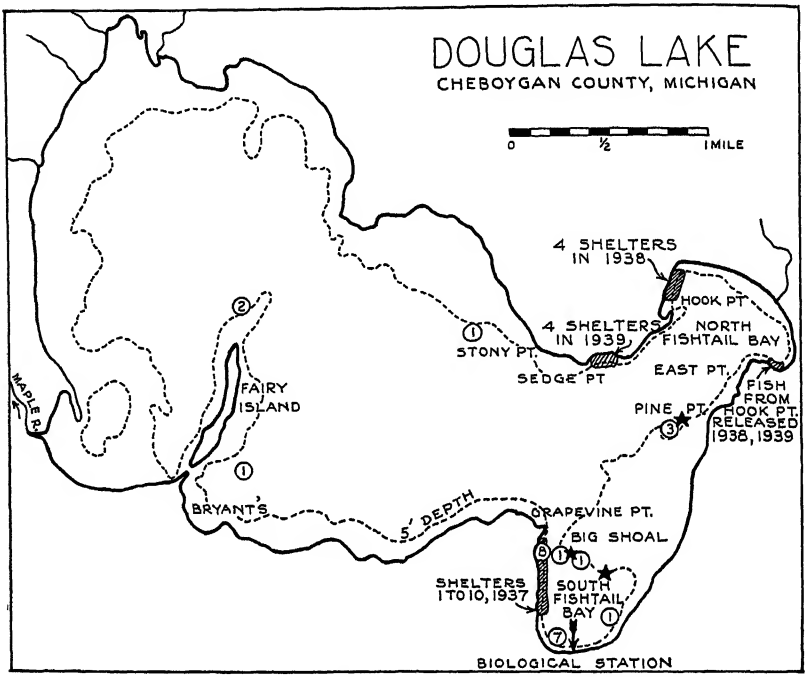

Fig. 1. Map of Douglas Lake, Michigan, showing points where fish were marked, released, and recaptured in a study of their movements. Stars mark the locations of Fyke net settings. Circles indicate the places where planted small-mouthed bass were recaptured; the figures within the circles give the number of bass retaken

North Fishtail Bay, in August, 1938. As the main focus of interest shifted to an analysis of fish movements, marking was continued at these locations and at other points in Douglas Lake in 1939. Small-mouthed bass transported from Lake Michigan and planted in Douglas Lake were marked before their release. In order to add to the little that is known of the wanderings of game fish in a lake, the data on the dispersion of these marked fish as determined by recaptures are presented in this paper.

A better knowledge of the movements of fish is one of the major problems that confront the fisherman and the scientist. "Where are the fish today?" is a stock phrase of the sportsman, and even the most experienced angler will excuse a poor day's fishing by saying that the fish have left his favorite fishing bed.

The practical fisheries manager is especially concerned with the distribution of fish. Should fish be planted at one convenient spot, or would the added expense of stocking fish at several points on a lake be justified? Is it possible that the condition in our lakes is analogous to that found in the deer country — starving fish in one part of a lake and an abundance of food in another? Will some sections be overfished while others are not fished at all? Does the installation of artificial covers make the taking of fish so easy as to deplete the stock? These are only a few of the questions that may be more adequately answered by a knowledge of the actions of fish.

To the fisheries biologist information on the shifting location of fish is essential in life-history and migration studies. What places are sought out for breeding by different species, and do they vie with each other for spawning grounds? Do they seek feeding areas where the young of certain species congregate?

Some insight into the movements of fish may be of value to general biologists and to specialists in fields other than fisheries research. In his study of the ecology of any organism the biologist will be aided by knowing where all fish are to be found at different times in a body of water. The possibility of racial segregation or even differentiation within a lake is another general problem in which such knowledge is of prime importance. The limnologist, too, may find that this information will throw new light on the various biological aspects of his studies, such as those on productivity.

ACKNOWLEDGMENTS

Again I should like to express my appreciation to Dr. A. S. Hazzard, director of the Institute for Fisheries Research, for assistance in planning this work, and to Dr. George R. La Rue, director of the Biological Station, for suggestions and equipment. As in former years, I owe a great debt to Dr. Carl L. Hubbs for guidance in this investigation and help in the preparation of the report. Thanks to the officials of the Michigan State Civilian Conservation Corps, labor was again furnished by selected enrollees.

METHODS OF MARKING FISH

1. *Fin clipping.* — The pelvic fins and pectoral fins were clipped on certain fish. Removing different fins made it possible to designate the fish of different locations distinctively. Regeneration of the

clipped fins was prevented by removing them at the base, with a pair of curved manicure scissors.

2. *Jaw-tagging.* — Numbered metal jaw tags (Shetter, 1936) were placed on the mandible maxillary or premaxillary. This method permits the tracing of the movements of individual fish.

3. *Silver wire.* — Fine silver wire was twisted around the right or left mandible of a small number of fish. The specimen was grasped in the left hand and held against the body. After a piece of the silver wire, cut to the proper length, had been inserted around the mandible, the ends were securely held, close to the fish's jaw, by the thumb and forefinger of the left hand, so that a loose loop was formed as the ends were twisted together by tagging pliers in the right hand and then bent back against the twisted part of the wire to prevent their catching on the net or other objects.

Rock bass (*Ambloplites rupestris*), pumpkinseeds (*Lepomis gibbosus*), and yellow perch (*Perca flavescens*) were marked by all three methods. Small-mouthed bass (*Micropterus d. dolomieu*) and large-mouthed bass (*Huro salmoides*) were fin-clipped in 1937 and tagged with metal jaw tags in 1938 and 1939. Northern pike (*Esox lucius*) were tagged with metal jaw tags.

METHODS USED TO RECAPTURE MARKED FISH

Several different methods were used to get returns on marked fish in Douglas Lake:

1. A 140-foot bag seine, made of $\frac{1}{4}$-inch mesh in the bag, of $\frac{3}{8}$-inch mesh next to the bag, and of $\frac{7}{8}$-inch mesh at the ends of the wings, was used for all seining. For deep shelters and weed beds a piece of net 6 $\times$ 80 feet was attached to the top of the center section of the seine to permit effective work in deeper water.

2. Posters were placed around the lake at the various resort centers asking fishermen to report any marked fish.

3. Two fyke nets, the property of the Biological Station, were used to catch fish on several drop-offs away from shore.

EXPERIMENTS AT GRAPEVINE POINT

In 1937 ten experimental fish shelters were built and placed on the shoal of Douglas Lake between Grapevine Point and the boat-

house of the University of Michigan Biological Station (see Fig. 1). A description of the area and of these constructions is given in a former paper (Rodeheffer, 1939). The first brush pile, called shelter 1, was placed just south of the little bay formed by Grapevine Point, in about 6 feet of water. All other constructions located on the 6-foot contour were numbered consecutively to the south. They were set approximately 80 feet apart except where control areas were designated. Here the distance between the installations was about 180 feet. Control areas established between shelters 2 and 3, 4 and 5, 6 and 7, 8 and 9, and south of shelter 10 were sections similar to the locations where fish protections were installed. This arrangement separated shelters 1 and 10 by approximately 1,100 feet. The devices were constructed and placed so that they could be pulled out to determine to what extent they were used by fish and the size and species of game fish found in them. Before the brush piles were removed the 140-foot bag seine was laid around them in the form of a semicircle. When the shelters were pulled shoreward the net was carefully drawn along behind, catching the fish in or near the artificial covers. The captured fish were identified, checked for previous markings, measured, and released.

In 1937, to discover if fish used the brush devices as summer habitats, the pelvic fins were clipped on all game fish before they were freed. On August 2, 4, and 6 the right pelvic fin was removed on all captured game fish; on August 23, 24, and 25 the left pelvic fin was clipped on the seined fish. Fish that were recaptured on August 2, 4, and 6 were recorded as being marked, then returned to the lake. When any fish with the right pelvic fin missing was retaken on August 23, 24, and 25, the left pelvic was also excised. Fish caught with both pelvic fins clipped were so recorded and set free. Table I presents the data of the species and numbers of fish with one or both pelvic fins removed. In 1938 the ten shelters were again pulled from the water and the fish counted, identified, checked for markings, and measured. On July 12 and 13 shelters 1, 2, and 10 were taken out and all game fish of sufficient size were tagged with metal jaw tags. Thirty-eight small-mouthed bass taken from all ten shelters and in four control areas between July 12 and August 26 were tagged.

To economize on time and tags in 1938 it was decided to clip the

TABLE I

NUMBER OF FISH, BY SPECIES, MARKED BY DIFFERENT METHODS AT GRAPEVINE POINT, DOUGLAS LAKE, AND PERCENTAGE OF THEM RETAKEN (ALL AT GRAPEVINE POINT) IN 1937, 1938, AND 1939

The percentages are based on all fish recaptured, whether once or more than once, because many of the fish were not marked so as to be individually recognizable and because the recaptured fish were released alive.

Date of original markings and recoveries	Rock bass	Yellow perch	Pumpkin-seeds	Small-mouthed bass	Large-mouthed bass	Northern pike	All species
Number marked Aug. 2–25, 1937, by clipping one or both pelvic fins....	1,320	663	262	210	22	...	2,477
Percentage recovered							
1937................	38.5	16.9	21.8	13.3	4.5	...	28.5
1938................	13.4	3.3	1.5	...	...	...	8.2
1939................	4.4	0.3	...	...	...	...	2.4
Number marked July 12–Aug. 26, 1938, by clipping one or both pectoral fins...........	582	566	95	...	...	...	1,243
Percentage recovered							
1938................	15.3	13.3	6.3	...	...	...	13.7
1939................	16.2	2.7	1.1	...	...	...	8.9
Number marked July 12–Aug. 26, 1938, with numbered jaw tags...	185	137	17	38	...	1	378
Percentage recovered							
1938................	13.0	13.1	11.8	47.4	...	200.0	16.9
1939................	3.8	...	...	...	...	...	1.9
Number marked July 24–Aug. 16, 1939, by silver wire...............	134	76	34	...	...	...	244
Percentage recovered, 1939	42.5	5.3	2.9	...	...	...	25.4
Number marked July 11–Aug. 16, 1939, with numbered jaw tags...	71	66	51	20	6	1	215
Percentage recovered, 1939	50.7	3.0	5.9	30.0	33.0	...	22.8
Total number marked by all methods 1937, 1938, and 1939...........	2,292	1,508	459	268	28	2	4,557
Percentage recovered							
Same year...........	31.2	14.0	15.0	19.4	10.7	100	23.1
Second year *.........	13.3	2.8	1.3	...	...	...	7.8
Third year *..........	4.4	0.3	...	...	...	...	2.4

* In percentage of marked fish then potentially available for recapture.

pectoral fins on all game fish except small-mouthed bass, large-mouthed bass, and northern pike at shelters 1, 4, and 10 at Grapevine Point. After July 13 all rock bass, yellow perch, and pumpkinseeds taken in the net had the right pectoral fin removed at shelter 1, the left pectoral at shelter 10, and both pectorals at shelter 4. All fish tagged or fin-clipped in 1938 were returned to the water at the

shelter after it had been replaced. The number and species of fish marked by the different methods in 1938 are given in Table I.

In 1939 all bass and northern pike were again tagged. At shelter 1 the right mandible of rock bass, yellow perch, and pumpkinseeds of sufficient size was marked with silver wire. Fish from shelter 10 were wired on the left mandible. At shelter 4 all fish were tagged with metal jaw tags. Table I details the number and species of fish marked in 1939 also.

RECAPTURES OF MARKED FISH AT GRAPEVINE POINT

Marking the fish caught at Grapevine Point made it possible to keep a record of the number of fish that were recaptured in 1937, 1938, and 1939. Fish were retaken (1) with pelvic fins missing — fish marked in 1937; (2) with metal jaw tags or pectoral fins clipped — fish marked in 1938; (3) with metal jaw tags or wired jaws — fish marked in 1939.

Table I gives the percentage of the fish recaptured each year, grouping them according to the different marking devices. The percentage of recovery for fin-clipped and wired fish was probably increased by reason of the fact that some fish were netted more than once. For the tagged fish, which were marked so as to be individually identified, it was found that of the fish tagged in 1938 at Grapevine Point one rock bass, two perch, and five small-mouthed bass were twice recovered in 1938, and that the one sunfish and the one northern pike were both taken a second time in that year. Of the rock bass tagged in 1938 three were again secured in 1939, and one of these was recorded five times. Of the fish individually tagged in 1939 six rock bass were recovered twice and five were caught thrice. None of the fish of the other species tagged were reseined more than once at Grapevine Point. In 1937 and 1939 a high percentage of retakes of the fish that were tagged the same year is indicated. Table I shows a declining number taken in 1938 and 1939 of those marked in 1937. A smaller percentage of the fish tagged in 1938 was retaken in 1938, with an unexplained increase in 1939 in the number of rock bass recaptured. There is also some difference in the percentages of renetted fish that were tagged, fin-clipped, or marked with silver wire. The number of returns by each marking method is, however, probably too small to warrant any conclusions as to which procedure is the most satisfactory.

THE MOVEMENTS OF FISH AT GRAPEVINE POINT

Tagging and fin-clipping in 1938 and 1939 at Grapevine Point made it possible to trace the movements of fish between shelters during the two summers. Table II specifies, for fish which were retaken, how far they had wandered from the point of original capture (or from the point of last capture in the case of the fish tagged for individual recognition) during the first and second years. It thus includes records for fish which are known to have been netted a number of times, and an exaggerated amount of traveling may be

TABLE II

MOVEMENTS OF MARKED GAME FISHES AT GRAPEVINE POINT, DOUGLAS LAKE, AS DETERMINED BY THE DISTANCE IN FEET BETWEEN POINTS OF CAPTURE AND OF RECAPTURE

For fish not individually marked it was necessary to assume that the movement was always from the point of original capture and marking. This circumstance may have exaggerated the amount of wandering indicated.

Species, year of recapture (and number of records)	Known distance traveled, in feet								
	0	80	170	260	340	430 or 520	600 or 690	780 or 860	1,040 or 1,120
Rock bass									
First year (206)....	105	30	1	10	27	13	7	12	1
Second year (101)..	46	14	..	10	10	10	1	3	7
Perch									
First year (98).....	39	32	7	3	6	1	4	2	4
Second year (15)...	13	2	..	..	..	..	..	..	..
Pumpkinseed									
First year (12).....	1	4	1	2	2	2	..	..	..
Second year (1)....	...	..	..	1	..	..	..	..	..
Small-mouthed bass									
First year (24).....	4	9	4	2	3	2	..	..	..
Second year (0)....	...	..	..	..	..	..	..	..	..
Large-mouthed bass									
First year (2)......	...	2	..	..	..	..	..	..	..
Second year (0)....	...	..	..	..	..	..	..	..	..
Northern pike									
First year (2)......	2	..	..	..	..	..	..	..	..
Second year (0)....	...	..	..	..	..	..	..	..	..
All species									
First year (344)....	151	77	13	17	38	18	11	14	5
Second year (117)..	59	16	0	11	10	10	1	3	7

indicated, since it is possible that some fish not individually marked swam to another shelter, making that cover a permanent habitat at which they may have been taken several times. For each such recapture the distance from the shelter where the fish had first been marked and released was recorded. The maximum number (five) of changes noted for a single fish were made by a rock bass which was tagged at shelter 2 on July 13, 1938, but not reseined in 1938. In 1939, on July 19, it was caught at shelter 2 (and therefore recorded as not having traveled). On July 28 it was taken 260 feet away, at shelter 4. On August 2 the same fish was recovered at shelter 2, so that 260 feet of travel was again listed. On August 4 it was seined at shelter 4, after another known shift of 260 feet. On August 16 the fish was caught again, this time at shelter 1 (340 feet from shelter 4). The sum of the known movements of this rock bass was 1,120 feet, but all the back-and-forth roaming, so far as is known, was within a distance of 340 feet. Table II indicates that the meanderings of fish are restricted within a given area. The larger number of fish were found to remain near the place of original capture. Rock bass show the greatest tendency to stay at (or to return to) the same refuge the second year. Yellow perch, usually considered a free-swimming fish, seem to live, during the first year, near the shelter where first captured. The few retaken in the area the second summer may merely indicate random swimming. Small-mouthed bass, although few were marked, showed restricted travel in one season and no indications of a return to the same region the second year. Pumpkinseeeds, large-mouthed bass, and northern pike were so few that conclusions regarding their wanderings are not warranted. It is most striking that not a single fish of the 4,557 marked at Grapevine Point from 1937 to 1939 was recovered at any other point in the lake. Lack of returns from sportsmen fishing in other parts of Douglas Lake might have been expected, as there is little angling here for pan fish, but a large amount of collecting was done around the eastern part of the lake, not only by the writer but also by other workers at the Biological Station, all of whom were looking for the marked fish. At Grapevine Point 1,051 recaptures were recorded during the year of marking, 320 during the following year, and 60 during the third year. What happened to the marked fish that were never renetted can only be guessed at. The rate of mortality among marked fish is not known but only seven marked rock bass and three marked perch

were found dead during the three years despite the fact that the beach around South Fishtail Bay was repeatedly traversed during all three summers. In 1939 a daily check was made of the entire shore from Grapevine Point to Pine Point (Fig. 1).

No doubt many fish, including, perhaps, some which had been marked, were eaten by gulls.

EXPERIMENTS AT NORTH FISHTAIL BAY

To gather more information regarding the movements of fish four additional brush shelters were constructed and placed in Douglas Lake, just north of Hook Point, in North Fishtail Bay, in July of 1938 (Rodeheffer, 1940). These shelters were removed and the fish caught at intervals between August 3 and 22, 1938, and between July 20 and August 9, 1939. In order to determine how rapidly and to what extent such shelters become repopulated all fish netted from these structures were carried a straight-line distance of about 0.6 mile across North Fishtail Bay, to be released in the small sheltered cove which lies to the east of East Point (Fig. 1). All game fish of sufficient size were tagged with metal jaw tags before being set free to see if any would return to the artificial covers. These operations also provided a further means of checking on the movements of fish marked at Grapevine Point and of those liberated at East Point. There were few returns from the fish that were tagged at Hook Point and put back into the water at East Point, but the individuals taken at various locations (as specified in Table III) suggest that these fish reacted similarly to planted fish in moving around somewhat at random. The fact that most of the recoveries from the shelters at Hook Point were of rock bass may be explained by the preference of rock bass for brush shelters (Rodeheffer, 1939, 1940). As indicating the limited natural movements of fish in the lake, it may again be pointed out that nineteen hauls, with a 140-foot seine, in 1938 and ten hauls in 1939 from shelters and control areas at Hook Point failed to capture any of the 4,557 marked fish released at Grapevine Point in 1937, 1938, and 1939.

The return of fish from East Point to Hook Point might be regarded as evidence of homing behavior, but no such conclusion is warranted by the facts at hand. Hook Point forms a natural trap and was a favorable and well-populated fish habitat even before the brush shelters were installed.

TABLE III

KNOWN MOVEMENTS OF FISH CAPTURED AND TAGGED AT HOOK POINT, DOUGLAS LAKE, AND RELEASED AT EAST POINT

Recoveries are indicated for the several points in Douglas Lake where collections were made in the given year.

Date of tagging and date and place of recovery	Rock bass	Yellow perch	Pumpkin-seeds	Small-mouthed bass	Large-mouthed bass	North-ern pike	All species
Number tagged in 1938..	205	160	70	20	6	3	464
Recoveries in 1938							
Hook Point........	16	3	...	1	..	..	20
Grapevine Point...	...	...	...	..	..	..	...
Pine Point........	1	...	...	..	..	..	1
Recoveries in 1939							
Hook Point.......	10	1	...	..	..	..	11
Sedge Point.......	...	...	...	..	..	..	...
Pine Point........	...	...	...	..	..	..	...
South drop-off, Big Shoal...........	...	...	...	..	..	..	...
East drop-off, South Fishtail Bay.....	...	...	...	..	..	..	...
Grapevine Point...	1	...	...	..	..	..	1
Number tagged in 1939..	115	98	74	9	5	2	303
Recoveries in 1939							
Hook Point........	4	1	1	..	..	..	6
Sedge Point.......	2	...	...	..	..	..	2
Pine Point........	...	...	...	1	..	..	1
South drop-off, Big Shoal...........	...	...	...	..	..	..	...
East drop-off, South Fishtail Bay.....	...	...	...	..	..	..	...
Grapevine Point...	...	...	...	..	..	..	...
Total number tagged in 1938 and 1939...	320	258	144	29	11	5	767
Total number recaptured in 1938 and 1939.	34	5	1	2	..	..	42

OTHER ATTEMPTED RECOVERIES

Investigations in 1937 and 1938 showed slight movement of fish in Douglas Lake. In attempting to determine how restricted the wandering is (and also to discover if fish of different sizes inhabit shelters at different depths), four ladder-shaped shelters (Hubbs and Eschmeyer, 1938, pp. 74–80, figs. 16–19) were made; two were placed in 5 feet of water, and two at a depth of 10 feet. These were installed in 1939, just east of Sedge Point, at a location approximately 0.6 mile distant in a straight line from the shelters at Hook Point and about 1 mile from the Grapevine Point constructions. These new

shelters were removed twenty times, control areas were seined five times, and weed beds west of the shelters were seined nine times between July 25 and August 17, 1939. For the shelters at a 10-foot depth and the weed beds a 6 × 80-foot section of seine was fastened to the top of the middle section of the 140-foot seine used in all seining operations. At Sedge Point twelve large rock bass were tagged, of which four were retaken; fifteen small-mouthed bass were tagged, and seven of these were renetted; seven large-mouthed bass and six northern pike were taken from the weed beds along the drop-off just west of the shelter, four large-mouthed bass and one pike being recaptured in the same weed beds. None of the fish tagged at Sedge Point were seined again at any other location, nor were any of the fish marked at Grapevine Point caught at Sedge Point. Of the fish set free at East Point, only two rock bass were recovered at Sedge Point (one was taken a second time).

The weed beds along the drop-off where Big Shoal and the deep water of South Fishtail Bay meet (see Fig. 1) was chosen as another spot for the attempted recapture of some of the marked fish. This area lies roughly 0.5 mile in a straight line from the Grapevine Point shelters, about 1.2 miles from the Sedge Point seining grounds, and about 1.5 miles from the Hook Point installations. Four seine hauls with the 140-foot bag seine, to which the 6 × 80-foot section of seine had been fastened, did not take any marked fish, although a total of 549 of the species marked in Douglas Lake were caught.

In a further effort to secure marked fish fyke nets were set in several places, as specified below, between July 28 and August 17, 1939. Twelve small-mouthed bass caught in the fyke nets were tagged and let go. One of these bass, tagged and liberated about 200 feet east of the point of Big Shoal, was later recaptured in a fyke net about 0.2 mile farther east along the south drop-off of Big Shoal. A small-mouthed bass released at East Point was later found in a fyke net at Pine Point. Eight large rock bass and eleven large pumpkinseeds were tagged and set free at the fyke net settings, but none of these were retaken. No other marked fish were taken in the fyke nets.

THE MOVEMENTS OF PLANTED SMALL-MOUTHED BASS IN DOUGLAS LAKE

On June 27 and July 13 and 24, 1939, a total of 271 small-mouthed bass of almost the legal size of 10 inches or larger were received from

Lake Michigan and released at the boat dock of the Biological Station, after they had been measured and weighed and scale samples had been taken. The shore from Grapevine Point to Pine Point was checked every morning for dead fish (8.5 per cent of the planted bass were found dead during the first nine days after planting). Posters were placed at the various resorts on the lake asking fishermen to report any tagged fish caught. Three per cent of the planted fish were retaken with nets and 6.3 per cent were caught and reported by fishermen between July 16 and September 1, 1939. The eight fish recovered with nets were all taken around the shelters at Grapevine Point. The seventeen small-mouths taken with hook and line were found in different parts of the lake. The place and number of recaptures are indicated by the circled figures on the map (Fig. 1). Two fish were hooked at the tip of Fairy Island, one in the bay near Bryant's, one at Stony Point, three at Pine Point, two along the south side of Big Shoal, one on the drop-off of the depression in South Fishtail Bay, approximately 0.4 mile east of the Biological Station, and seven in the weed beds on the drop-off at the Biological Station boathouse. The number of planted small-mouthed bass retaken is too small to justify very definite conclusions, but even this scant information seems to indicate that planted fish do more roaming than the native fish.

DISCUSSION AND SUMMARY

The results of three summers' work at Douglas Lake quite definitely indicate that there is little movement of the native game fish from one part of the lake to another. Of all the fish marked at several locations in Douglas Lake and loosed at the point of capture none were retaken in distant parts of the lake. Recaptures were made only in the near vicinity of original capture and release.

Many game fish (4,557) were marked for three consecutive years at Grapevine Point but none were caught again at any other location. Seining operations were performed at several places located 0.5 of a mile to 1.5 miles in a straight line from Grapevine Point. A limited number of fish (forty) were tagged and freed at Sedge Point in 1939. All recoveries of these marked fish (sixteen) were made in the vicinity of Sedge Point.

Fyke net settings, the nearest of which was only about 800 feet from the Grapevine Point shelters on the south drop-off of Big Shoal,

did not take any marked fish from Grapevine Point. Weed-bed seinings along the southeast shore of South Fishtail Bay failed to bring in any marked fish.

In the work at Hook Point in 1938 and 1939 no marked fish were netted from any other place of release except a few which had been caught at Hook Point but liberated near East Point.

In 1938 and 1939 posters were placed around Douglas Lake asking fishermen to report the catching of any marked fish. Only two rock bass were reported, both of which were tagged in 1938 at Hook Point and released at East Point. One was caught at Pine Point in 1938, the other was secured at the shelters at Hook Point in July, 1939. The paucity of these returns may be explained in part by the fact that little fishing is done for rock bass, yellow perch, or pumpkinseeds in Douglas Lake.

This evidence brings out rather conclusively the fact that there is little movement of marked native fish in the eastern end of Douglas Lake when such fish are released at the point of first capture. They do not seem to migrate to new locations that offer similar habitats. One factor which may tend to inhibit such dissemination is the fact that Big Shoal almost separates North Fishtail Bay from South Fishtail Bay. The water over the greater part of Big Shoal is shallow (5 feet or less in depth) and almost devoid of cover; and the shoal is surrounded on three sides by deep water with rather steep drop-offs which may tend to retard fish from swimming across the wide, open shoal. The deep waters of the lake may also act as barriers to the free dispersion of fish.

Recaptures of the marked fish at Grapevine Point indicate a restricted movement even within a short distance along one shore. The evidence that fish wander little in Douglas Lake is in line with the fact that the fishing boats congregate in certain favored spots, which are known to the local guides who make a business of taking sportsmen to good fishing grounds. Some locations are known as bass fishing grounds, others as pike grounds. Indications are that fish congregate in these particular places year after year, since the guides use them every season and are very particular to get on the exact spot, for they claim that a difference of a few boat lengths will affect the fishing. Of course the abundance of fish on certain fishing grounds may be due more to the attractiveness of the habitat to the fish than to their restricted movements.

That the fish populations are localized in Douglas Lake is supported by observations made in 1921 by Dr. Carl L. Hubbs and Dr. Charles W. Creaser, who found evidence that the perch in the northwestern part of the lake are of the type occurring in Bessy Creek and Lancaster Lake, of which it is the outlet, rather than of the type occupying other parts of Douglas Lake (personal communication). Investigations by Dr. Frank E. Eggleton present further evidence that there are distinct perch populations in Douglas Lake (personal communication).

There is other evidence that Douglas Lake is not a simple unit. Limnological investigations (Welch, 1928, and Welch and Eggleton, 1932, 1935) disclose that the six major submerged depressions in the main basin of Douglas Lake act as independent lakes, each with its own physical, chemical, and biological characteristics.

The capture at Sedge Point, Grapevine Point, and Pine Point of fish that had been seined at Hook Point and returned to the water at East Point suggests that native fish which are taken from the place of capture and planted in another part of a lake do move from the point of release to other places in the lake.

Recoveries at numerous points in Douglas Lake of planted small-mouthed bass indicate that such fish wander more than native fish. The stocked bass seem to move around in the lake almost at random except that they apparently seek some shelter, since all recaptures were made either at the brush constructions or in weed beds.

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A LIMNOLOGICAL INVESTIGATION OF A PERMANENTLY STRATIFIED LAKE IN THE HURON MOUNTAIN REGION OF NORTHERN MICHIGAN *

LLOYD L. SMITH, Jr.

DURING the progress of a fisheries investigation on the waters of the Huron Mountain Club in Marquette County, Michigan, observations were made on an uncommon type of lake. The physical and chemical conditions existing at all seasons of the year indicate permanent stratification, with an incomplete vernal and autumnal overturn. References in the literature to similar American bodies of water are few. Eggleton (1931) gave some evidence that Kirkville Green Lake in New York State may be stagnant or, at least, that permanent stagnation is possible. The physiography of its basin and certain characteristics in the distribution of its bottom fauna point to this conclusion. Welch (1935) mentioned small lakes which show physiographic characters indicating incomplete overturn. Ruttner (1931) discussed similar conditions in a tropical lake. Findenegg (1933, 1937) reported on lakes in central Europe that had incomplete overturn and permanent chemical stratification. Yoshimura (1937) investigated several lakes in Japan with permanent stagnation and lists a group of similar lakes in various parts of the world.

The author wishes to thank Messers Charles H. Hodges, Jr., and Wetmore Hodges, who have made the study possible by their financial support; the management and membership of the Huron Mountain Club for coöperation in the field work; Drs. Carl L. Hubbs and Paul S. Welch for their helpful suggestions and criticism of the manuscript; and Mr. J. P. Harris for assistance in laboratory examinations.

* This study was made as a part of a doctoral dissertation presented to the Department of Zoölogy of the University of Michigan.

PHYSIOGRAPHY

Canyon Lake is at the western end of an old range of pre-Cambrian granite hills lying adjacent to the southern shore of Lake Superior. The region was covered by the Wisconsin ice sheet, which scoured off the peaks and left rounded knobs that rise 1,000 feet above the present level of the Great Lakes. During the Algonquin stage of the last glaciation the waters impounded by the retreating ice completely covered the basin of Canyon Lake. With the subsequent recession of the waters this lake was isolated, and it now lies 233 feet above the present level of Lake Superior (Scott, 1921; Leverett, 1929).

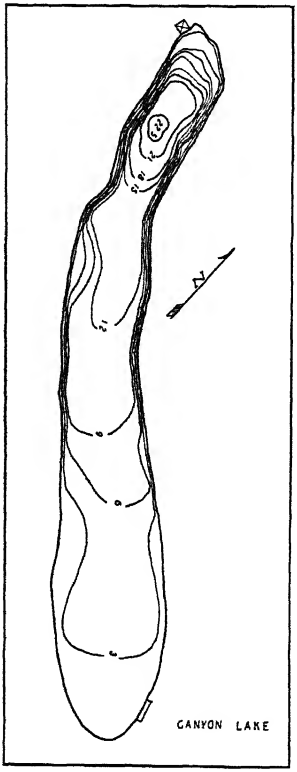

FIG. 1. A contour map of Canyon Lake in the Huron Mountains, Marquette County, Michigan. Contour lines are at 3-meter intervals

Geologically the lake belongs to a type infrequent in Michigan. According to Scott (1921), it is a fault lake lying in a depression created by vertical displacement of the rock strata and subsequently dammed with morainic material. The basin is long and narrow, and covers an area of slightly more than ten acres (Fig. 1). Sheer crystalline rock cliffs rise out of the water to a height of 50 feet and form most of the lateral margins. Near the southeast end these walls recede from the water and give place to a swamp which blocks the overflow from the lake. A maximum depth of 22.5 meters is attained near the north end of the lake. As Figure 1 indicates, the shoal area is limited to a small region at the shallow end. All other shores plunge off almost vertically into deep water.

The watershed is small and for the most part is composed of granite rock overlain with a thin glacial soil. Except on the bare rock surfaces the area supports a hemlock–hardwood forest. The

precipitous banks of the lake give foothold to a few white cedars and pines. Bottom soils are composed more or less uniformly of a grayish green pulpy peat containing much organic detritus from the surrounding forest floor. Submerged aquatic vegetation is sparse and restricted to the first three meters of shoal water at the shallow end.

The high banks and the surrounding hills almost eliminate wave action during the open-water season. An ice sheet formed in late November and remaining until early May closes the lake during the winter months. The ice reaches a thickness of 18 to 24 inches and is covered with 1 to 3 feet of snow.

METHODS AND PROCEDURE

Ten series of observations over a period of two years were taken on Canyon Lake to secure data for all the limnological seasons. A maximum-minimum thermometer was used for all temperature determinations. Dissolved oxygen, total alkalinity, free CO_2, and pH determinations were made in accordance with the procedure outlined in *Standard Methods for the Examination of Water and Sewage* (1933). Ten-liter samples of water from various depths were secured with a two-liter Kemmerer-Juday water bottle and were poured through a no. 25 bolting-silk plankton net to remove free-floating forms. The concentrated plankton was preserved in a 10 per cent formalin solution. Samples of the bottom soil, taken with a 6×6-inch Eckman dredge, were mixed with clean water and sieved through no. 40 brass screens, and the concentrated bottom organisms and detritus were preserved in a 10 per cent formalin solution. The minnow population was sampled with a net 6 feet in diameter operated from a boat. The larger species of fish were sampled with experimental gill nets, which ranged from $\frac{3}{4}$- to 2-inch bar mesh. Inaccessibility of the lake during the winter months limited the observations at that season to chemical analyses.

PHYSICOCHEMICAL CHARACTERISTICS

1. Temperature

Surface temperatures in Canyon Lake vary directly with the air temperature and follow it more closely than they do in the larger adjacent bodies of water. As will be pointed out later, the shallow

depth of the epilimnion accounts for this rapid response. Below 8 meters the temperature remains constant at 4.4° C. at all seasons. A thermocline, which may be formed as early as the middle of May (Fig. 2), persists until late September or early October. Its upper limits lie between 2 and 3 meters; the lower ones, between 6 and 8 meters. It is formed near the surface as a relatively thin layer (Fig. 2), but with the advance of summer it gradually increases in thickness by depression of the lower limit (Fig. 3). During the

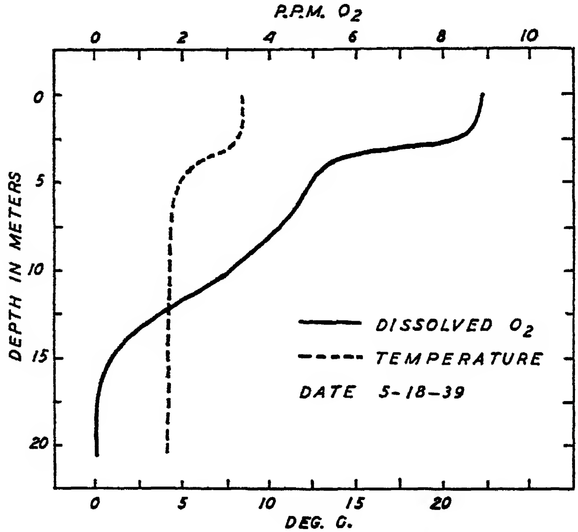

Fig. 2. Temperature and dissolved oxygen concentration from surface to a depth of 22 meters on May 18, 1939

hottest part of the year the thermocline, strictly defined, starts almost at the surface (Fig. 4). The rapid decline of temperature near the surface virtually eliminates the epilimnion and prevents circulation of the surface water. With the cooling of the surface waters in the fall the thermocline becomes less distinct and finally disappears, which allows some degree of circulation in the upper waters (Figs. 5–6). The clarity of the water and the restricted area of the basin would normally cause higher surface temperatures and a lower position of the thermocline, but the abrupt and closely approximated walls of the lake shade the waters except for a short time during midday.

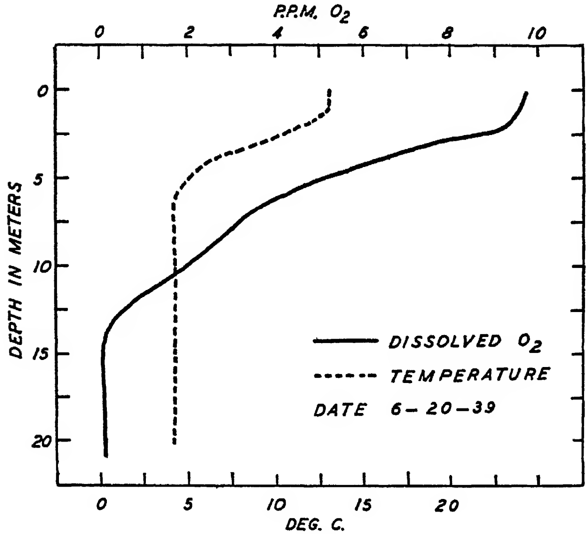

FIG. 3. Temperature and dissolved oxygen concentration from surface to a depth of 22 meters on June 20, 1939

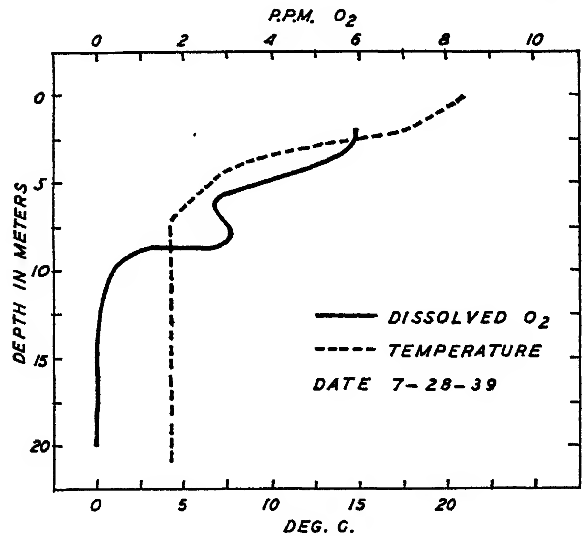

FIG. 4. Temperature and dissolved oxygen concentration from surface to a depth of 22 meters on July 28, 1939. The irregularities near the thermocline are correlated with the density of phytoplankton

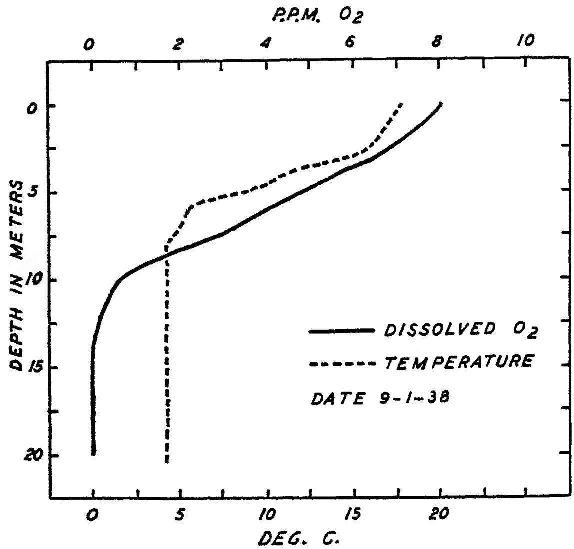

FIG. 5. Temperature and dissolved oxygen concentration from surface to a depth of 22 meters on September 1, 1938

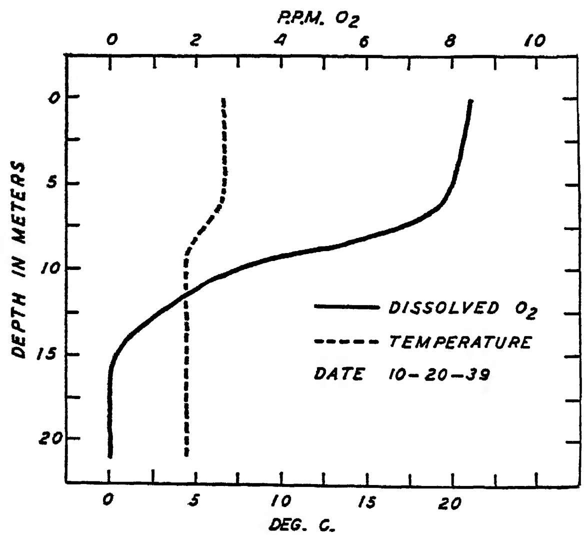

FIG. 6. Temperature and dissolved oxygen concentration from surface to a depth of 22 meters on October 20, 1939

Aside from the shallow position of the thermocline there is nothing particularly significant about the temperature phenomena. The thermal characteristics, however, are the only physicochemical factors which vary normally with the change of the seasons. Unusual chemical conditions exist throughout the year and give strong indication of permanent water stratification.

2. Dissolved Oxygen

Dissolved oxygen is not present below 16 meters at any season, and during the summer the last traces are found at 12 meters (Fig. 4). In May oxygen occurs to a depth of 16 meters (Fig. 2). As the season advances it is gradually eliminated from the lower strata until in late July none is found below 12 meters. At this time the curve of oxygen distribution is very irregular in the lower levels of the thermocline because of the operation of biotic factors. By September 1 these irregularities have straightened out, and there is a gradual decrease in concentration from the surface to the 12-meter depth (Fig. 5). By late October the overturn of the upper waters has begun, and oxygen is again present at 15 meters (Fig. 6). It will be noted that the overturn is incomplete and that the distribution of oxygen is not uniform, but shows a gradual decrease from the surface to the point of disappearance. In late winter oxygen in the upper strata is reduced to 3.9 parts per million, whereas the lower strata remain anaërobic (Fig. 7).

3. Total Alkalinity and Free Carbon Dioxide

Even more marked than the distribution of dissolved oxygen is the extreme variation from surface to bottom of the total alkalinity and the free CO_2. The alkalinity, expressed as parts per million of calcium carbonate, ranges from a minimum of 12 at the surface to a maximum of 270 at the bottom. Down to a depth of 15 meters the concentration increases to approximately three times the value at the surface, and then jumps rapidly to twenty times the surface value at the greatest depth. Minor variations occur during different seasons (Figs. 8–12), but the shape of the distribution curves remains essentially the same. During late July conditions in the thermocline cause irregularities similar to those noted for oxygen.

The content of free CO_2 varies from 1 part per million at the surface to a maximum of 232 parts per million at the 21-meter level.

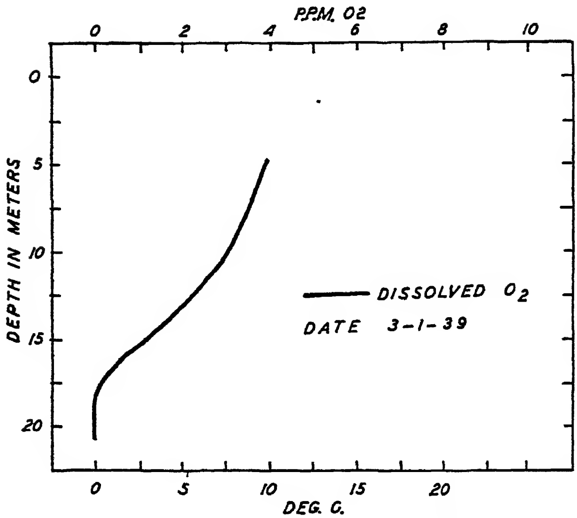

FIG. 7. Dissolved oxygen concentration on March 1, 1939. Eighteen inches of ice covered the lake at the time of this observation

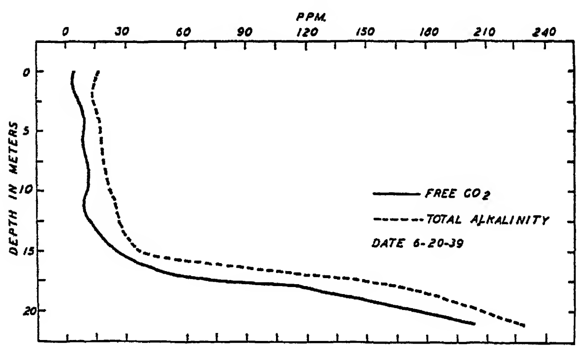

FIG. 8. Total alkalinity, expressed as parts per million of calcium carbonate, and free CO_2 concentrations from surface to a depth of 22 meters on June 20, 1939

The gradual increase in concentration to a depth of 15 meters and the rapid increase below that point are as notable as for the total alkalinity. The curves for free CO_2 remain relatively constant at all seasons and follow the general shape of the alkalinity curves. Winter observations were not made at the maximum depths for either CO_2 or

total alkalinity, but the conditions down to 18 meters were very similar to those in late October and May.

When brought to the surface from 18 meters and below the water samples effervesced because the release of pressure and increase in

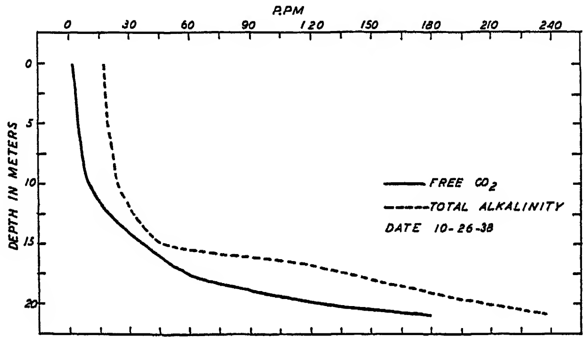

Fig. 9. Total alkalinity, expressed as parts per million of calcium carbonate, and free CO_2 concentrations from surface to a depth of 22 meters on October 26, 1938

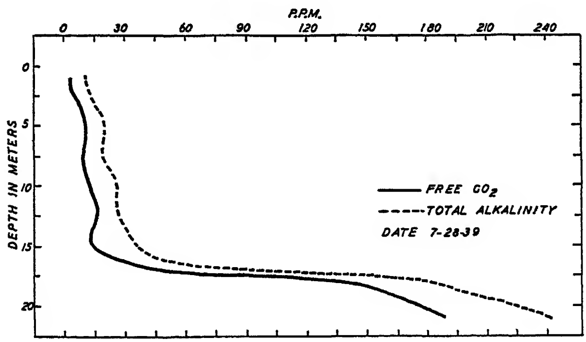

Fig. 10. Total alkalinity, expressed as parts per million of calcium carbonate, and free CO_2 concentrations from surface to a depth of 22 meters on July 28, 1939

temperature liberated a gas held in solution. No field equipment for the analysis of this gas was available. Since a flame test showed no methane and since no odor of hydrogen sulfide was present, the gas was assumed to be CO_2. The high concentration of CO_2 in the water and the precipitation of ferric salts in sample bottles after a period of standing lend support to this suggestion.

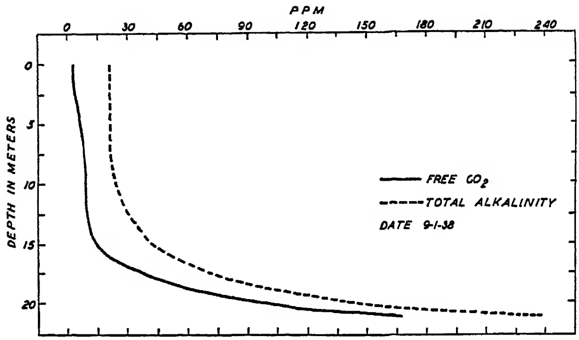

FIG. 11. Total alkalinity, expressed as parts per million of calcium carbonate, and free CO_2 concentrations from surface to a depth of 22 meters on September 1, 1938

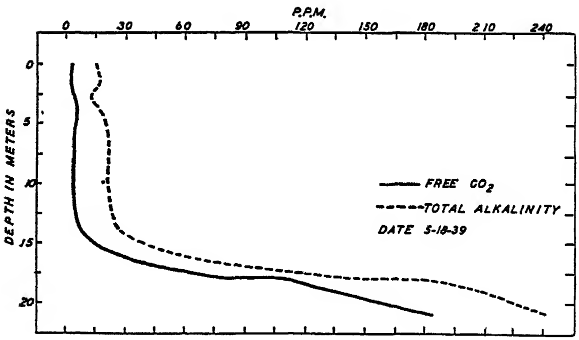

FIG. 12. Total alkalinity, expressed as parts per million of calcium carbonate, and free CO_2 concentrations from surface to a depth of 22 meters on May 18, 1939

4. Hydrogen-Ion Concentration

The pH ranges from 7.0 at the surface to 6.0 at the bottom, with no very significant seasonal changes. The highest hydrogen-ion concentration occurs during the winter and the lowest during the spring and fall (Fig. 13). During midsummer there is a sharp drop of pH in the region of thermal stratification. The relatively high pH associated with the high concentration of dissolved CO_2 is probably to be explained by the action of natural buffers.

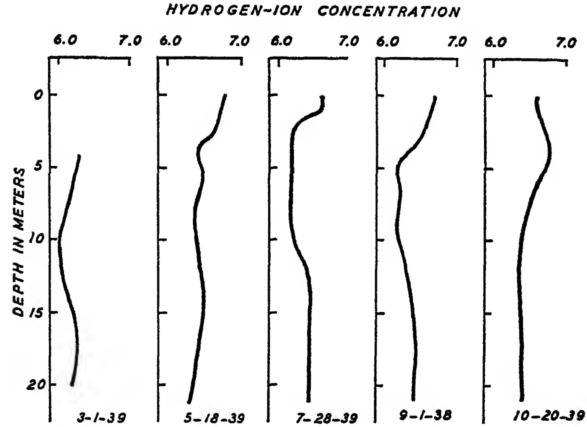

FIG. 13. Hydrogen-ion concentration at different seasons. The depression in July, 1939, is correlated with the activity of the plankton at that level

BIOLOGICAL CHARACTERISTICS

As would be expected from the alkalinity of the surface waters, the biological productivity of the lake is low, with few species and a light concentration of individuals. The fish population consists of the lake chub, *Couesius plumbeus,* and the speckled trout, *Salvelinus fontinalis.* Hubbs (1929) lists the chub as the only native species and ascribes the absence of other species to the early isolation of the lake in postglacial time.

There are not many benthic organisms, and the number of species is small. The most prominent species are *Hyalella knickerbockeri* in the shoal waters and *Corethra sp.* and several species of Chironominae in deeper water. At all seasons of the year the bottom soils below 16 meters are free of macroscopic organisms. In midsummer none are found below 10 meters. There is a marked irregularity of distribution, emphasized by two concentration zones. During late July the upper zone lies between 1 and 3 meters and the lower between 6 and 7 meters (Fig. 14). At this time the lower concentration is dominated by Chironominae larvae, but as fall approaches it begins to move down, until in late October it lies at 8 meters, with *Corethra sp.* and Chironominae dominating the population. Along with this downward shift is the appearance of *Corethra* at 15 meters

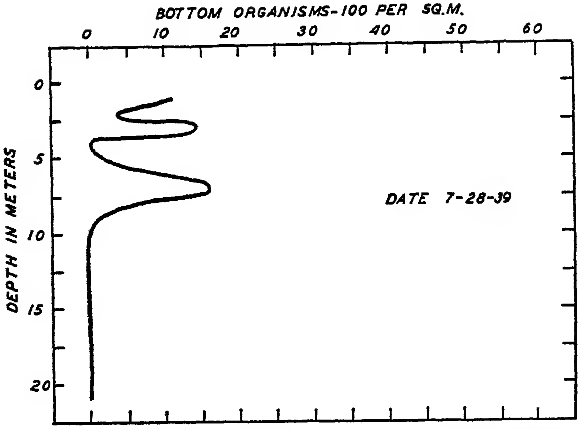

FIG. 14. Distribution of bottom organisms on July 28, 1939. The concentration zone, composed of *Corethra* and Chironominae, lies at a depth of between 6 and 7 meters

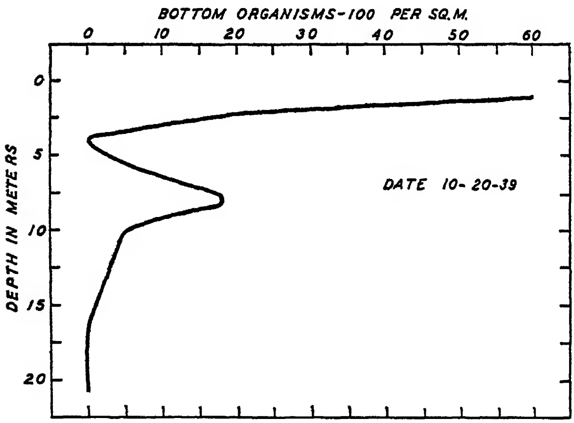

FIG. 15. Distribution of bottom organisms on October 20, 1939. The concentration zone lies at a depth of 8 meters, and organisms have penetrated to 15 meters

(Fig. 15). Coincident with changes in the location of concentrations are the increase of oxygen in the upper strata and the penetration of traces to 16 meters (Fig. 6). The concentration zone during midsummer lies in the lower stratum of the thermocline, or just below it. With the disappearance of thermal stratification it moves to

greater depths. Eggleton (1931) has shown that this phenomenon is more or less typical of eutrophic lakes.

In May, shortly after the ice goes out, a concentration zone composed entirely of *Corethra* lies at 14 meters (Fig. 16). As the season progresses the zone moves up to the summer level, and all organisms disappear from the lower strata. The tendency toward downward movement in the fall and the low position of the zone just after the spring break-up suggest that the greatest number of organisms occur at the lower level of available oxygen during the

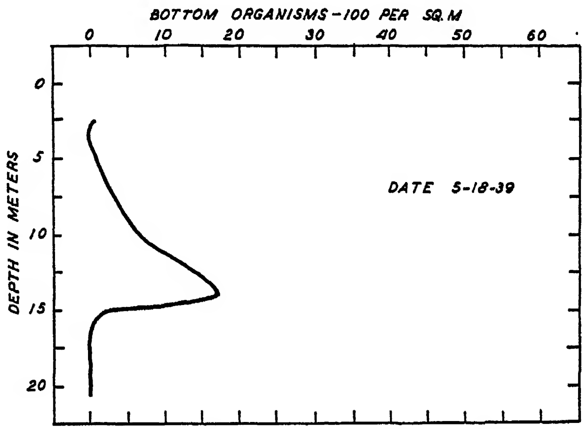

FIG. 16. Distribution of bottom organisms on May 18, 1939. The concentration zone, composed of *Corethra*, lies at a depth of 14 meters

winter months. Eggleton (1931) showed this to be the usual condition in the lakes he studied. A peculiarity which occurs at all seasons is the complete absence of organisms at the 4-meter level. Since there is no apparent temperature or chemical condition correlated with this barren area, the cause may be some peculiarity of the bottom soil.

In general, the distribution of the bottom organisms seems to depend on the availability of oxygen. The permanent depletion of oxygen in the lower levels is correlated with the absence of bottom forms, and the seasonal disappearance of life from the middle zone is likewise coincident with oxygen removal.

In this lake there is nothing remarkable about the species of

plankton or their distribution, and they tend to bear out the assumptions derived from the other limnological data. The number of both species and individuals is relatively low, and nothing approaching a typical plankton surge has been observed. The zooplankton is dominated by the Rotifera; the phytoplankton, by *Tabellaria sp.*, *Dinobryon sertularia*, and *Ceratium hirundinella*. The scarcity of blue-green algae and the small number of phytoplankters may be due in part to the low temperature of the water and the few hours of sunlight which the rock walls permit to strike the water.

The waters of the stagnation zone are dominated at all seasons by *Keratella cochlearis*, *Ceratium hirundinella*, and *Tabellaria sp.* The only cladoceran observed in these strata was *Bosmina longispina*. At one period in late summer a considerable increase in *Dinobryon* occurred and was noticeable as deep as 15 meters. Since there were no apparent physical or chemical changes at this level and since the increase was not reflected by other species, the abundance of this particular form may have been caused by the sinking of individuals from overlying layers. At 20 meters the plankton consisted entirely of *Keratella cochlearis*, *Ceratium hirundinella*, *Tabellaria sp.*, and *Diatoma sp.* The population is marked by the absence of deep-water forms which are commonly found in cold, soft lakes without stagnation.

From Table I, which shows the total number of plankton forms and the total number of zooplankters per liter at various depths and seasons, it will be noted that the decrease in numbers from surface to bottom is largely due to the decrease in phytoplankton. The irregularity of oxygen distribution in late July previously pointed out is correlated with the concentration of algal forms in the thermocline.

The following list of plankton species, although by no means complete, contains the conspicuous and numerically dominant forms.

ROTIFERA: *Polyarthra platyptera, Triarthra longiseta, Pedetes saltator, Keratella cochlearis, Keratella quadrata, Notholca longispina, Rattulus sp.*
CLADOCERA: *Bosmina longispina, Daphnia longispina.*
DINOFLAGELLIDA: *Ceratium hirundinella.*
PHAEOPHYCEAE: *Dinobryon sertularia.*
DIATOMACEAE: *Tabellaria sp., Diatoma sp., Fragillaria sp.*

In some of the surface samples *Microcystis*, *Diaptomus sp.*, *Cyclops sp.*, and *Ceriodaphnia sp.* were occasionally present. A few

TABLE I

TOTAL NUMBER OF PLANKTON INDIVIDUALS AND TOTAL NUMBER OF ZOOPLANKTERS PER LITER

Depth in meters	July 28, 1938		Sept. 1, 1938		Oct. 25, 1938		May 18, 1939		Oct. 21, 1939	
	Total plank.	Zoo-plank.	Total plank.	Zoo-plank.	Total plank.	Zoo-plank.	Total plank.	Zoo-plank.	Total plank.	Zoo-plank.
0	58,936	21,425	9,918	178	1,115	1,052	91	28	6,836	4,510
2	1,977	279	...	...	...	...	210	60	...	...
3	...	...	4,417	139	293	146	35	28	...	...
4	...	...	1,281	223	...	...	158	52	...	...
5	...	...	...	...	471	339	...	...	...	...
6	448	122	...	...	...	...	36	28	315	289
7	...	...	244	110	...	...	...	...	...	...
8	1,236	710	...	...	...	...	...	...	...	...
10	1,000	1,000	...	...	46	46	77	14	81	44
14	...	...	...	...	...	...	14	12	...	...
15	206	123	1,426	106	50	29	...	...	40	21
18	...	...	...	...	...	...	19	15	...	...
20	42	39	83	35	...	...	...	...	52	20

other species of phytoplankton and rotifers formed inconspicuous components of the population.

From consideration of the physical, chemical, and biological data it appears that Canyon Lake has a more or less normal circulation zone extending down to a depth of 15 meters and a permanent stagnation zone below that level. This permanent stratification limits the distribution of macroscopic bottom organisms and strictly aërobic plankton forms to the upper strata of water, and makes the lower strata practically barren.

SUMMARY

1. The deep strata of the lake remain constantly at 4.4° C.

2. There is a sharp thermal stratification, with the upper limits of the thermocline lying between 2 and 3 meters.

3. The lake contains no trace of dissolved oxygen below 16 meters at any time of the year.

4. The total alkalinity and free CO_2 show a great variation from surface to bottom which does not change significantly during the year.

5. The lake is a soft-water type in its upper strata and a modified hard-water type in the lower strata.

6. No macroscopic bottom organisms occur below 16 meters.

7. Above 16 meters the seasonal changes in the benthos are similar to those in a eutrophic lake.

8. The plankton species dominant in the stagnation zone are those which frequently occur in anaërobic conditions.

9. The lake has the appearance of two separate bodies of water, one superimposed upon the other: the upper active and the lower stagnant.

10. Permanent stratification and the resulting physical, chemical, and biological phenomena are caused by the low temperature of the bottom waters, the precipitous banks, and the lack of wind agitation.

MINNESOTA DEPARTMENT OF CONSERVATION
ST. PAUL, MINNESOTA

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ZOOGEOGRAPHY OF NAIADES IN THE GRAND AND MUSKEGON RIVERS OF MICHIGAN AS RELATED TO GLACIAL HISTORY

HENRY VAN DER SCHALIE

ALTHOUGH Michigan lies wholly within the St. Lawrence drainage basin, the fresh-water mussels of the rivers of southern Michigan are entirely Mississippian. Furthermore, the areas drained by the highly productive streams in and south of the valleys of the Saginaw and Grand rivers, which were formerly connected, are very similar in their soil composition, topography, and climate. There are no great natural barriers to distribution over land, yet there are marked faunal differences in the distribution of the species of naiades in the various streams of this region. These differences have not been explained satisfactorily by any of the observable variations in the present conditions of the drainage basin. In the past practically all of them have been well explained as due to some event in glacial history, and this continues to be the best way of accounting for them.

There were two major avenues by way of which Mississippian naiades entered southern Michigan. These pathways have been discussed by Bryant Walker (1898, 1913). One entrance into southern Michigan, elaborated upon by Ortmann (1924) and van der Schalie (1938a), was through the Maumee River outlet to the Wabash and Mississippi rivers. This confluence permitted the thirty species of mussels now occupying Lake Erie and its tributaries to enter southeastern Michigan. The other avenue, the one by which naiades entered southwestern Michigan, was through the Des Plaines River and the Chicago outlet to the Mississippi River. It is with the latter that we are primarily concerned at present. Some details of the glacial history as it relates to the events attending the receding ice lobes of the last or Wisconsin stage of glaciation in the western portion of Michigan will be discussed later, in explaining the distribution of mussels in the Grand and Muskegon rivers.

A study of the naiades of the Muskegon and Grand rivers suggests

TABLE I

FAUNAL COMPARISON OF THE NAIADES IN THE GRAND AND MUSKEGON RIVERS

Species	*Grand River*	*Muskegon River*
Quadrula pustulosa	+	−
Quadrula quadrula *	+†	−
Cyclonaias tuberculata	+	−
Amblema costata	+	−
Amblema peruviana	+	−
Fusconaia flava	+	+
Pleurobema cord. coccineum	+	+
Elliptio dilatatus	+	+
Strophitus rugosus	+	+
Anodonta grandis	+	+
Anodonta imbecillis	+	−
Anodontoides ferussacianus	+	+
Lasmigona compressa	+	+
Lasmigona complanata	+†	+†
Lasmigona costata	+	+
Alasmidonta calceolus	+	+
Alasmidonta marginata ‡	+	+
Obliquaria reflexa	+†	+†
Proptera alata	+†	+†
Leptodea fragilis	+†	+†
Obovaria olivaria *	+†	−
Actinonaias carinata ‡	+	+
Actinonaias ellipsiformis ‡	+	+
Micromya iris	+	+
Ligumia recta latissima	+	+
Lampsilis siliquoidea	+	+
Lampsilis ventricosa	+	+
Truncilla donaciformis	+†	−
Truncilla truncata *	+†	−
Dysnomia triquetra	−	+†
Total	29	21

* Reported by R. E. Coker (1921).
† Species entering mouth of river from Lake Michigan.
‡ Species with discontinuous distribution.

that the Muskegon was formerly a tributary of the Grand River. A comparison of the species inhabiting the two rivers is presented in Table I. The Muskegon River is shown to harbor only twenty-one of the twenty-nine species found in the Grand River. Five of them, marked by daggers, are known to be common to the Great Lakes (Goodrich and van der Schalie, 1932), and they probably entered the lower portion of the Muskegon River from Lake Michigan (Table II).

TABLE II

Distribution of Naiades in the Muskegon River

Species	Tributaries									Main River														
	1. Wolf Cr., 10 mi. s. of Houghton	10. Dishwash Cr., at Marion	11. Middle Branch R., 2 mi. s. of Marion	19. E. Br. Little Muskegon R., Mecosta	21. Tamarack Cr., at Howard City	9. W. Br. Clam R., 5 mi. e. of Marion	8. Clam R., 7 mi. e. of Marion	20. Little Muskegon R., sw. of Altona	18. Ryan Cr., 2 mi se. of Big Rapids	2. Between Higgins and Houghton lakes	3. 3 mi. below Houghton Lake	4. 7 mi. w. of Houghton Lake	5. ¼ mi. w. of Leota	7. Just w. of Temple	12. 11 mi. s. of Marion	13. 1 mi. ne. of Evart	14. Below Hersey	15. Above Paris	16. At Big Rapids	17. Below Roger's Dam	22. Below Croton Dam	23. 3 mi. below Newaygo	24. At Bridgeton	25. 10 mi. ne. of Muskegon
Elliptio dilatatus	..	..	..	..	..	..	..	13	30	33	71	..	3	7	20	75	49	55	..	3	2	8	..	1
Fusconaia flava	..	..	..	..	..	..	..	1	20	2	2	1	10	2	5	10	6	9	..	1	1	27	1	..
Pleurobema cord. coccineum	..	..	..	..	..	..	..	..	6	..	..	..	1	..	..	..	3	..	..	1	1	1	1	..
Strophitus rugosus	..	..	..	..	..	..	5	4	5	1	3	..	1	1	4	2	17	14	1	5	47	21	1	1
Lasmigona costata	..	..	..	..	1	..	..	4	1	..	1	..	..	..	5	12	14	3	2	2	1	..	..	..
Lasmigona compressa	..	1	..	4	1	1	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Anodonta grandis	..	..	..	..	..	..	..	..	..	..	38	..	..	..	..	..	..	..	.	1	1	2	1	..
Alasmidonta calceolus	2	..	1	..	3	4	3	..	6	..	..	..	..	..	2	1	1	..	..	..	..	..	..	..
Alasmidonta marginata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	5	4	..	2	..
Anodontoides ferussacianus	..	..	6	2	..	16	38	1	1	..	..	..	..	2	..	..	..	..	..	..	2	..	..	..
Micromya iris	..	..	..	..	..	..	..	..	4	30	5	..	..	..	..	..	..	..	..	..	..	..	..	..
Lampsilis siliquoidea	18	1	11	..	..	6	20	2	3	..	46	..	77	45	31	57	25	25	17	3	15	5	..	..
Lampsilis ventricosa	..	..	..	..	..	..	..	..	..	23	3	..	..	..	6	..	..	1	..	3	20	3	..	..
Ligumia recta latissima	..	..	..	..	..	..	..	..	..	..	1	..	..	1	25	29	32	3	..	7	4	2	..	..
Actinonaias carinata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	16	8	6	13	2	5	4	31	5	1
Dysnomia triquetra	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6	..	..
Proptera alata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..
Total no. of species	2	2	3	2	3	4	5	6	9	5	9	1	5	6	9	8	10	8	4	11	12	10	7	3

The remaining sixteen are primarily a medium-sized river assemblage. Two of them, *Actinonaias carinata* and *Alasmidonta marginata*, are normally inhabitants of rivers and have never been reported from lakes. Consequently, in the Muskegon River they have *discontinuous* distribution. Both are common in the Grand River, where also they are discontinuous in distribution. These data had led to the belief that at one time in its drainage history the Muskegon River was a tributary of the Grand River. This view is substantiated by the glacial history of these streams, since it is known that the Muskegon River was at one time connected with the Grand River through the valley of the present Rouge (Rogue [1]) River.

The course of the Muskegon River as it flowed through the valley of the Rouge River (north of Grand Rapids) was traced by Leverett and Taylor (1915, p. 227): "At one time during the recession of the ice border the Muskegon, which received drainage from the Lake Michigan lobe on the west and the Saginaw Bay lobe on the east, ran southward past Rice Lake in southeastern Newaygo County, its altitude near Rice Lake being 800 feet above sea level. It followed Rouge River to its junction with Grand River near Grand Rapids and probably continued southward (for a time at least), leaving the Grand River near Grand Rapids."

At the meeting of the Michigan Academy in 1902 Dr. Leverett discussed this drainage course in detail, but his address was never published. He assures me, however, that the entire geomorphology of the present Rouge River valley — its extensive width, the distribution of the sands and gravels, the swamp that now exists at the head of this valley, the shape of Rice Lake, and the present position of the Saginaw and Lake Michigan moraines, which indicates that ice once plugged the mouth of the Muskegon River — points to a former connection between the Muskegon and the Grand rivers.

There is considerable skepticism among zoologists, geologists, and physiographers regarding the value of distributional studies of naiades in tracing stream confluence. One prominent geomorphologist is convinced that the distribution patterns of mussels can be best explained on the assumption of a transfer of these animals by passive agents, such as birds and mammals. A well-known conchologist has expressed himself as in agreement with the contentions of

[1] Two spellings, "Rouge" and "Rogue," appear on maps. Old residents of the region drained by this river use "Rogue River."

the physiographer. I have pointed out earlier (van der Schalie, 1939) that the evidence that birds and mammals are the agents responsible for the distributional features observed among naiades in nature is meager and wholly inadequate. Yet in spite of the imposing array of *factual* data in opposition to their theory the protagonists of passive migration of mussels by agents other than fishes are obviously still unconvinced. This attitude is unfortunate, since their interpretation undoubtedly hinders progress in the utilization of the sound evidence that the distribution of naiades can give in tracing drainage lines of the past.

A common mussel of southwestern Michigan is *Actinonaias ellipsiformis*. It was found at many stations in the Grand River (Table III). On the other hand, *Lampsilis fasciola* is well represented in the three main rivers of southeastern Michigan (van der Schalie, 1938a, p. 14). Both species inhabit rivers, are associated ecologically with streams of medium size, and usually are not found in the Great Lakes. Hence both are at present *discontinuous* in their respective ranges. The distribution pattern of each is shown graphically in Figure 1. If naiades are distributed by birds and mammals, it would be interesting to have an explanation of the reason why neither of these species, *ellipsiformis* and *fasciola*, has been carried across the east–west drainage divide, particularly since the tributary streams of the two major drainage systems so closely approximate each other. Dr. Wilbert B. Hinsdale (1931, p. 6), in discussing famous portages in Michigan, points out that only a low divide separates the Raisin River from both the Kalamazoo and the Grand rivers. In regard to the divide between the Huron and the Grand rivers he says: "Mr. N. F. Wing, of Grass Lake, states that forty years ago he actually paddled across the divide between Portage River and Otter Creek, through the lowlands and swamps, without having to get out of his canoe. During high water the Indians certainly could have done the same thing; the only obstructions from Lake Erie to Lake Michigan would have been rapids and fallen timber." Nevertheless, owing to restrictions attending the ecology and distribution of naiades these species have not crossed this divide since glacial time. Certainly if birds and mammals are a factor in mussel distribution, such a restriction would not be likely to persist.

When the distribution of the species mentioned above is considered in relation to the late glacial history of the drainages inhabited by

TABLE

DISTRIBUTION OF NAIADES

Species	Tributaries																			
	76. Rush Cr., 2 mi. e. of Hudsonville	83. Cedar Cr., 4 mi. n. of Rockford	82. Rouge R., 2 mi. n. of Rockford	11. Red Cedar R., 1 mi. s. of Fowlerville	12. W. Br., 4 mi. w. of Fowlerville	13. 3 mi. e. of Webberville	14. 2 mi. nw. of Webberville	15. ¼ mi. w. of Williamston	16. 5 mi. w. of Williamston	17. Below Okemos	18. Lookingglass R., 3 mi. n. of Perry	19. 9 mi. w. of Laingsburg	20. Near DeWitt	22. 5 mi. w. of Lansing	23. 2 mi. ne. of Eagle	49. Wabasis Creek	50. Flat River, at Gowan	51. Creek, outlet Lincoln Lake	48. Flat R., s. of Belding	47. 2 mi. ne. of Lowell
Quadrula pustulosa	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Cyclonaias tuberculata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Amblema costata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Amblema peruviana	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Fusconaia flava	..	..	..	..	13	..	1	19	4	15	2	8	18	12	7	1	..	9	..	..
Pleurobema cord. coccineum	..	..	5	..	..	..	..	17	1	14	..	1	13	11	..	..	..	4	..	..
Elliptio dilatatus	..	..	7	..	..	..	..	1	7	63	7	..	2	43	53	..	2	..	6	3
Strophitus rugosus	..	..	..	..	..	..	..	22	6	23	1	3	2	9	20	..	4	14	1	7
Anodonta grandis	..	..	..	2	5	..	..	1	1	..	..	4	2	..	..	..	..	1	1	..
Anodonta imbecillis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Anodontoides ferussacianus	5	1	..	8	52	..	1	4	2	2	4	3	3	1	..	2	..	..	5	15
Lasmigona compressa	1	3	..	1	7	..	1	1	..	3	1	..	1	..	..	..	5	..	..	1
Lasmigona complanata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Lasmigona costata	..	..	..	..	..	..	2	1	1	1	..	..	..	..	..	..	1	..	..	3
Alasmidonta calceolus	..	6	2	3	24	1	3	15	8	21	38	2	29	6	15	..	..	1	1	.
Alasmidonta marginata	..	..	..	..	..	..	..	..	1	1	..	..	..	..	9	..	..	..	2	7
Proptera alata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Leptodea fragilis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	.
Actinonaias carinata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Actinonaias ellipsiformis	..	.	5	..	..	..	..	42	90	124	38	..	25	37	66	1	10	5	13	..
Micromya iris	..	..	..	.	..	..	.1	23	151	150	1	16	14	22	23	..	2	11	1	.
Ligumia recta latissima	..	.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	.6
Lampsilis siliquoidea	..	..	..	..	40	1	7	19	1	4	33	26	12	1	..	..	..	1	..	..
Lampsilis ventricosa	.	..	..	..	..	..	..	15	6	9	..	..	1	4	2	1	2	2	3	5
Truncilla donaciformis	..	..	..	..	.	..	..	..	..	..	.	..	..	..	..	..	..	..	..	..
Total no. of species	2	3	4	4	6	2	7	13	13	13	9	8	12	10	8	4	7	9	9	8

III

IN THE GRAND RIVER

															Headwaters and Main Stream																
41. Mud Cr., 7 mi. n. of Nashville	43. Cedar Cr., ½ mi. w. of Quimby	42. Thornapple R., 1 mi. s. of Vermont	44. 1½ mi. w. of Quimby	45. 1 mi. below Alaska	28. Maple R., 3 mi. se. of Ovid	27. 2 mi. e. of Ovid	30. 1½ mi. sw. of Bannister	31. 9 mi. ne. of Maple Rapids	32. Pine Cr., 1 mi. n. of Maple Rapids	33. Maple R., at Maple Rapids	37. 2 mi. ne. of Lowell	80. Crockery Cr., 3 mi. ne. of Nunica	79. 1 mi. e. of Nunica	77. 7 mi. ne. of Eastman	1. Grass Lake	5. Portage R., 12 mi. ne. of Jackson	9. Sandstone Cr., 6 mi. se. of Tomkins	8. At Tomkins	2. Grand R., 3 mi. s. of Jackson	3. 4 mi. se. of Jackson	21. 2½ mi. se. of Dimondale	34. At Dimondale	35. 2 mi. sw. of Eagle	36. 1 mi. se. of Portland	25. ½ mi. s. of Muir	38. 2 mi. e. of Ionia	39. At Saranac	40. 4 mi. w. of Saranac	46. 1 mi. e. of Ada	52. At Plainfield	81. 3 mi. sw. of Nunica
..	..	..	..	..	..	..	..	..	..	..	3	..	..	2	..	..	..	..	..	..	..	..	..	..	7	17	5	27	8	..	1
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	2	6	2	7	1	..
..	..	..	..	2	..	..	2	8	15	2	5	1	4	3	..	..	..	3	..	..	..	..	..	..	2	12	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3	13	3	5	7
..	..	17	..	1	..	..	6	34	4	..	8	5	..	..	..	..	3	12	15	8	1	5	49	16	11	37	2	22	19	5	..
..	..	..	..	1	..	..	..	1	..	4	2	..	..	..	..	..	..	..	..	1	4	1	2	14	1	5	..	2	1	4	..
..	1	18	15	13	..	..	..	..	1	2	20	11	19	2	..	..	38	..	1	25	13	18	8	40	8	17	6	6	14	11	1
1	..	2	13	..	3	13	1	..	4	..	1	7	..	8	..	..	..	2	6	6	6	24	11	10	14	4	5	4	7	2	..
..	..	..	..	5	15	..	..	6	5	7	18	5	11	21	4	..	..	..	2	2	3	8	..	6	3	4	3	8	3	..	1
..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	2	..	..	..	..	..	..	..	..	..	..	..	..
1	..	8	..	..	31	13	1	..	22	..	3	1	1	..	..	..	..	5	1	1	1	1	12	2	..	2	..	..	..	..	..
..	..	2	..	..	3	..	..	..	1	..	..	..	..	..	..	..	..	..	3	..	..	1	1	1	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	6	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	1	..	2	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	1	..	5	7	..	5	3	1	3	7	8	..
..	4	25	10	..	1	25	..	..	2	..	..	..	..	..	..	..	3	1	..	22	9	3	3	5	..	..	..	..	..	..	..
..	1	..	..	1	..	..	..	..	..	1	1	..	..	..	..	..	..	..	..	..	1	2	..	..	5	13	4	..	20	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	2	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	4	15	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
..	..	..	..	1	..	..	..	..	..	..	1	..	1	..	..	..	..	..	..	..	5	4	1	3	..	5	1	10	7	14	..
..	2	3	45	7	8	38	1	..	3	..	..	..	..	..	..	..	12	21	2	..	3	40	13	19	..	2	..	..	7	..	..
..	1	7	20	..	..	1	..	1	2	..	..	..	..	..	..	..	12	72	19	73	9	10	..	..	1	1	1	..	5	1	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3	..	2	2	2	..	..
..	1	17	3	..	..	..	1	7	7	2	2	..	3	2	20	2	8	29	12	68	..	..	..	..	6	..	..	..	..	1	1
..	2	3	5	..	..	..	2	..	..	..	..	1	..	..	..	..	..	8	..	4	..	7	1	..	8	3	1	3	1	2	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2
2	7	11	7	9	6	5	7	6	11	7	12	8	8	9	2	1	6	9	10	11	11	14	11	10	14	15	13	12	15	11	7

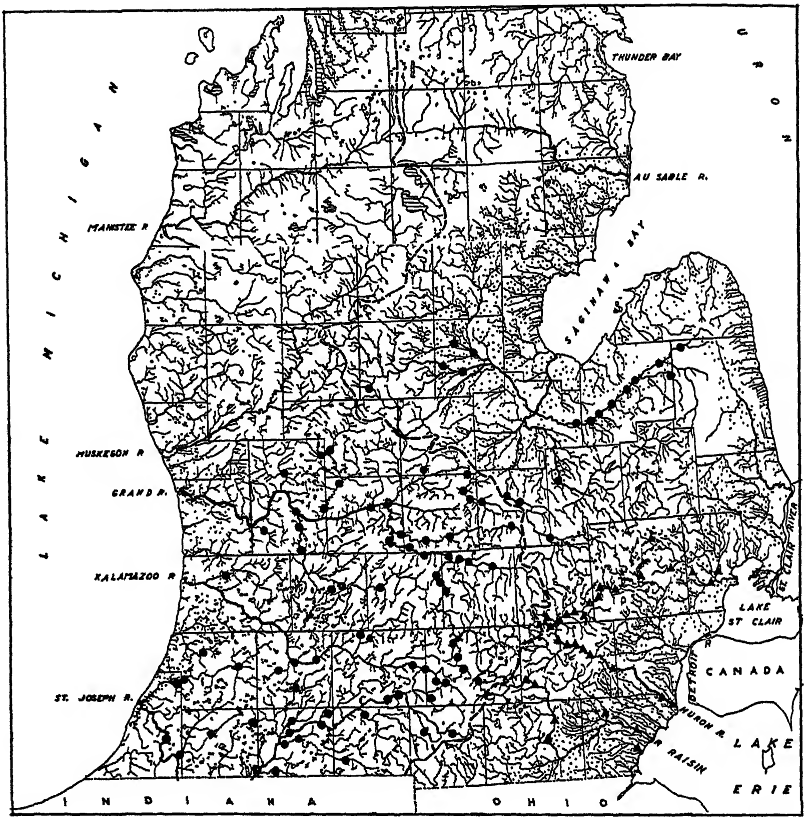

FIG. 1. Distribution of *Actinonaias ellipsiformis* (circles) and *Lampsilis fasciola* (triangles) in southern Michigan

them, a remarkable set of correlations is evident. The rôle of glacial history in the distribution of *Lampsilis fasciola* has already been discussed (van der Schalie, 1938a, pp. 10–14). Consequently, only the conditions affecting the distribution of *Actinonaias ellipsiformis* will be considered at this time. It not only occurs in all the rivers on the west side of the state south of and including the Grand, but has also entered the tributaries of the Saginaw drainage basin (Fig. 1). This pattern of distribution is to be expected in view of present knowledge concerning the confluence that formerly existed between the Saginaw and Grand River drainages. According to Russel and

Leverett (1908, p. 13), that connection persisted while Lake Warren discharged its waters across the Saginaw–Grand divide. This confluence accounts for the invasion of the Saginaw River drainage by *ellipsiformis* and other river-inhabiting species of mussels. No explanation has yet been advanced, however, for the absence of *ellipsiformis* in the Muskegon River drainage. Both *Actinonaias carinata* and *Alasmidonta marginata* probably entered the Muskegon during the period when the Grand and Muskegon rivers were connected, as has already been discussed. The fact that *ellipsiformis* did not enter the Muskegon simultaneously may mean that it invaded the Grand River drainage at a period when the connection between that river and the Muskegon no longer existed, but before the severance of the confluence between the Saginaw and Grand River drainages.

There is strong evidence that faunal differences between areas should be explained on the basis of glacial history rather than by ecological differences in the habitats provided by the areas. A recent textbook entitled *Ecological Animal Geography* (Hesse, 1937, p. 132) contains the statement that "broader areas, with other conditions equal, in general have a richer fauna. A principal reason may be that they afford a wider range of habitat conditions, and thereby increase the possibilities for the formation of species by adaptation." It is obvious, however, that such reasoning would hardly explain the large difference between the number of naiades at present found in Lake Erie, which has thirty species, and in Lake Michigan, which has, perhaps, a maximum of ten. Nor would ecology by itself be a sufficient reason for the faunal differences observed in the Grand and Muskegon rivers (Table I).

Nevertheless, a knowledge of the ecology of the various species of naiades has proved of considerable value in an interpretation of the origin of present distribution patterns of species within the different drainages. Figure 2 and Tables II–III are submitted to show graphically and in condensed form the ecological and distributional data on naiades in the Grand and Muskegon rivers. The information contained in the tables will be summarized here.

As has already been suggested, the naiades of the Muskegon River constitute an aggregation which is clearly that of a former tributary of the Grand River. This relationship becomes evident if one compares the faunal list in Table II (Muskegon River species) with that in Table III for the Red Cedar drainage, which is at present

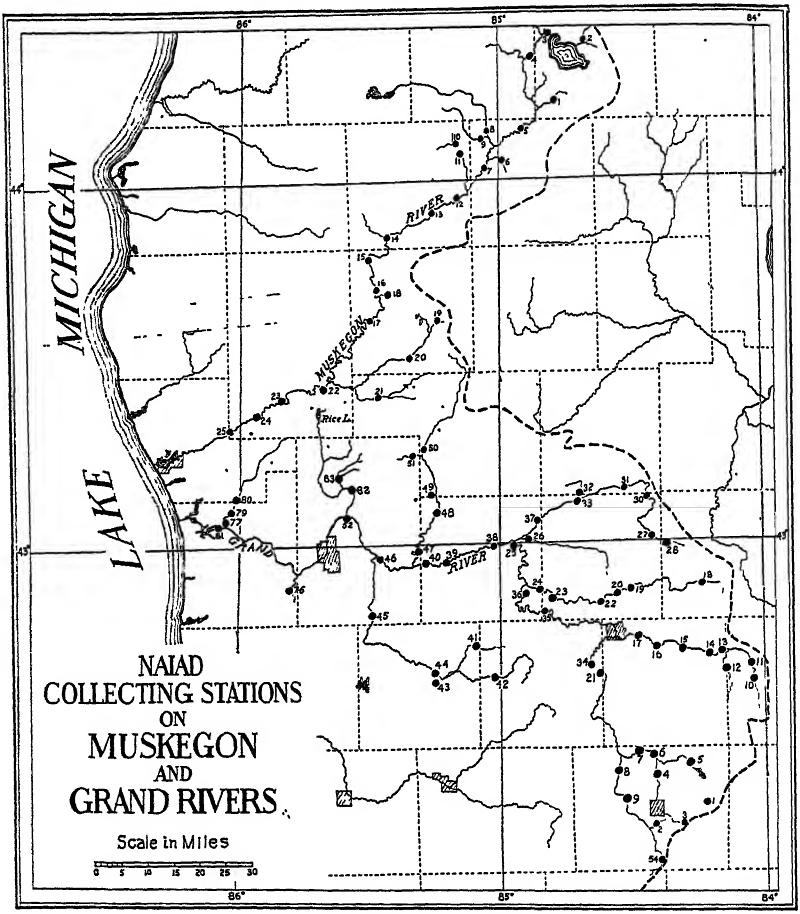

FIG. 2

a tributary of the Grand River. These lists are so nearly identical that the faunas of the Muskegon River and the Red Cedar River show virtually the same relation to the Grand River fauna. It will be noted, however, that four species occurring in the Muskegon River are absent from the Red Cedar. The presence of two of them, *Proptera alata* and *Dysnomia triquetra*, in the Muskegon River is obviously accounted for by the fact that they invaded the lower Muskegon River from Lake Michigan. The other two species, *Actinonaias*

carinata and *Ligumia recta latissima*, are ecologically large-river forms (see Table III), which are in the Muskegon because at one time it joined the lower portion of the Grand. The ecological evidence tends to confirm the view that the Rouge River valley served as the former line of junction between these major drainage systems. Further evidence that species usually associated with lower reaches of a river may invade smaller tributaries near the mouth of the river is seen in the occurrence of *Quadrula pustulosa*, a large-river species (Table III), which was found near the mouth of Maple River and Crockery Creek. In addition, the invasion of Crockery Creek by *Lasmigona complanata*, *Proptera alata*, *Leptodea fragilis*, and *Actinonaias carinata* also illustrates this point. As is shown in the tables, none of these species are associated with creeks farther upstream.

Since the naiad fauna of the Muskegon River so closely approximates the fauna inhabiting the larger tributaries of the headwaters in the Grand River, it is possible to group the naiades of both drainages into the following ecological assemblages:

Three species common to creeks:

Lasmigona compressa
Anodontoides ferussacianus
Alasmidonta calceolus

Fourteen species occurring under medium-sized–river conditions:

Fusconaia flava
Elliptio dilatatus
Pleurobema cordatum coccineum
Amblema costata
Strophitus rugosus
Anodonta grandis
Anodonta imbecillis
Alasmidonta marginata
Lasmigona costata
Micromya iris
Ligumia recta latissima
Lampsilis siliquoidea
Lampsilis ventricosa
Actinonaias ellipsiformis

Five species common under the large-river conditions found in the lower portion of the main stream:

Quadrula pustulosa
Cyclonaias tuberculata
Amblema peruviana
Actinonaias carinata
Ligumia recta latissima

Several other naiades are clearly associated with the extreme lower reaches of both drainages because of conditions obtaining there. These studies, as well as those of other drainages in Michigan, have shown that the following species are invaders from Lake Michigan:

Lasmigona complanata
Proptera alata
Leptodea fragilis
Truncilla donaciformis
Dysnomia triquetra

Four other species found only below Grand Rapids, reported by Coker and others (1921, p. 95), should be added to the last group:

Quadrula quadrula	Obovaria olivaria
Obliquaria reflexa	Truncilla truncata

With the exception of the differences just listed the naiades of the Grand River reported by Coker and others (1921) are essentially the same as those shown in Table III. Dredging operations in the lower Grand River between Grand Rapids and Grand Haven have been largely responsible for the present scarcity of the mussels in that zone.

Since many factors are causing the depletion of the indigenous fauna, it becomes increasingly important that information regarding ecology and distribution be gathered before the damage becomes too extensive. In the Grand River other agents besides dredging are and have been particularly harmful. Sewage and many kinds of industrial wastes have entered it below Jackson, Lansing, and Grand Rapids. There has been in addition an excessive amount of mussel-shell gathering with the use of apparatus injurious to the mussel beds (van der Schalie, 1938b). The power dams in the Muskegon River are most harmful to the naiades of that drainage, since species normally inhabiting a stream are usually eliminated from the impounded water behind dams. Such obstructions also hinder the normal migration of fishes, the carrying agents for fresh-water mussels. Lumbering activities in the headwaters and pollution near the mouth have likewise contributed toward eradicating naiades in the Muskegon River.

Variation in the nacreous color of certain mussels has always been of interest. Most species have a white nacre, but in several the nacre is consistently purple or pink. Occasionally a species, such as *Elliptio dilatatus*, which is normally purple, will produce white-nacred specimens. In this general connection it was particularly striking that so many white-nacred specimens of *dilatatus* were found in the Muskegon River. There is no conclusive information about whether nacreous color is a response to environmental conditions or is due to genetic factors. Table IV shows the relative proportion of white to colored specimens of *dilatatus* in the Muskegon River.

The proportion of specimens with colored nacre to those with

TABLE IV

Nacreous Color Variation of *Elliptio dilatatus* at Stations in the Muskegon River Drainage

Station number	Location of station	Nacre		Total
		Purple	White	
2	River, between Houghton and Higgins lakes	16	17	33
3	River, 3 miles below outlet of Houghton Lake	43	28	71
12	River, 11 miles south of Marion	14	6	20
13	River, 1 mile northeast of Evart	56	19	75
14	River, at junction with Hersey Creek	36	13	49
15	River, above Paris	29	26	55
18	Ryan Creek, 2 miles southeast of Big Rapids	19	11	30
20	Little Muskegon River, near Altona	8	5	13
Total		221	125	346

white nacre is almost two to one. All available evidence (van der Schalie, 1938a, pp. 48–49) indicates that there is practically no correlation of nacreous color with the range of the species. Further studies on the genetics of the color may prove more successful in solving the problem of causal relations responsible for this variation.

SUMMARY

The zoogeography of the Mississippian naiad fauna of southern Michigan is best explained in terms of glacial history. Naiades reached southeastern Michigan from the Mississippi River by way of the Wabash and Maumee rivers; the species in streams of southwestern Michigan came by way of the Des Plaines River and the Chicago outlet to the Mississippi. Faunal evidence indicates that the Muskegon River was formerly a tributary of the Grand. Ecological and distributional data support the contention that the Rouge River valley formerly connected the Muskegon River with the Grand. Twenty-nine species of fresh-water mussels inhabit the Grand River; twenty-one are reported in the Muskegon. The species are grouped ecologically into four major assemblages.

University of Michigan

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THE HERMAPHRODITE GLAND AND GERM CELLS OF *VALLONIA PULCHELLA* MÜLL.*

MARGARET ESTHER WHITNEY

CONTENTS

* Contribution from the Department of Zoölogy, University of Michigan.

INTRODUCTION

THE numerous studies of hermaphrodite mollusks have brought to light a variety of interesting and unusual reproductive conditions. Of particular interest relative to this paper is the capacity for self-fertilization revealed by some of the forms studied. Though in general hermaphroditism in this group has been regarded as of the "insufficient" type, the laying of fertile eggs in strict isolation has been recorded in a number of instances. Ikeda (1937) lists reports of this kind covering thirty species of Pulmonata, belonging to ten different genera. Some authors have questioned how far these laboratory results could be considered indicative of natural processes. For the most part they have been obtained with animals which copulate freely in nature.

The study presented here concerns *Vallonia pulchella* Müll., a small land snail, which gives evidence of a natural physiological isolation in contrast to one artificially brought about. Steenburg (1918) and Watson (1919) describe the hermaphrodite organs from minute dissections and call particular attention to the absence of male ducts in the majority of the specimens examined. A similar reduction of male organs has been found in *Acanthinula aculeata* (Boycott, 1917; Steenburg, 1918) and also in *Bullinus contortus* (Larambergue, 1930, 1932, 1933). In some cases the aphallic state is interpreted by Boycott as being a structural simplification associated with diminution in absolute size.

Elimination not only of male ducts but of male cells, resulting in parthenogenesis, has been reported for *Paludestrina jenkinsi* by Robson (1923) and for *Campeloma rufum* by Van Cleave and Altringer (1937) and Mattox (1937).

In a preliminary paper I have described the egg-laying habits of *Vallonia pulchella*, the hatching of the eggs, and the growth of the young to maturity (Whitney, 1938). Under laboratory conditions isolated individuals laid an average of one egg a day over a period of several months. The young were well developed and active when hatched. Desiccation and low temperatures were found to have an important modifying effect upon the egg-laying function and upon development. Copulation was never observed. Individuals isolated from the time of hatching laid eggs from which young hatched, and some of the latter reared in isolation reproduced

in like manner. This observation continued for several successive generations.

These macroscopic observations formed a basis for the present microscopic study to determine further details of reproduction in *Vallonia pulchella*, particularly those relating to self-fertilization. The possibility of parthenogenesis was not entirely excluded, even though male cells were present, since in many hermaphrodites various barriers against self-fertilization exist.

Some of the interesting phases of the problem concerned the origin and differentiation of male, female, and nutritive cells; possible abnormalities of maturation resulting in atypical sperm and ova, such as have been reported for other mollusks; possible cyclic conditions; modifications imposed by the small size of the animal, and by environmental factors; and, finally, the survival value of the conditions found, so far as this could be inferred. Self-fertilization and parthenogenesis have been cited as contributing factors in bringing about wider distribution of certain molluscan forms, especially under the influence of civilization (Robson, 1923; Boettger, 1931). Observations of *Vallonia* suggested similar interpretations.

I take this opportunity to express appreciation to Professor Peter Okkelberg for having directed this study, to members of the Departments of Zoölogy and Botany and of the Museum of the University of Michigan for valued suggestions and assistance, and to members of the Botany and Zoölogy Departments of Butler University, Indianapolis, Indiana, for many favors.

GENERAL REVIEW OF THE LITERATURE

The problems studied necessitate a review of some of the literature bearing on hermaphroditism and self-fertilization among the mollusks in general and the pulmonates in particular. References having to do with more detailed aspects of the study will be reserved for sections in which they apply.

Furrow (1937), reviewing the work on sex in the Mollusca, distinguishes two types of hermaphrodite glands: the "segregated," in which there is an anatomical separation of male and female elements; and the "unsegregated," in which male and female cells arise within the same cysts. He points out, however, that in the latter there is a segregation in the time of development of male

and female cells which prevents self-fertilization. The intervals vary considerably, and under experimental conditions may be shortened almost to the point of complete elimination, when self-fertilization becomes possible. Furrow cites examples of such experimental alterations of the sexual cycle in the pond snails *Planorbis* and *Lymnaea*. Crabb (1927, 1928), however, expresses the view that self-fertilization is the normal, not the unusual, method of reproduction in the species of *Lymnaea* which he studied.

There has been some disagreement regarding barriers against self-fertilization. If such barriers are postulated, production of fertile eggs by isolated hermaphrodites must be attributed to parthenogenesis. As evidence in favor of self-fertilization rather than parthenogenesis in some of the forms studied authors have cited the presence of ripe sperm and eggs in the same cysts at practically all times, the giving off of two polar bodies, the development of two pronuclei, and the numerical ratios exhibited by the offspring of isolated heterozygotes (Crabb, 1927; Larambergue, 1930; Ikeda, 1937). In the parthenogenetic snail *Campeloma rufum*, in which no male elements whatever were to be found, Mattox (1937) describes a type of oögenesis in which only one polar body is produced, with no evidence of synapsis or reduction.

In general, one gathers from a survey of the literature that conditions in many hermaphrodite mollusks are such as to permit self-fertilization in varying degrees, and that in some this phenomenon may possibly occur naturally in combination with cross-fertilization.

MATERIALS AND METHODS

For this study specimens of *Vallonia pulchella* Müll. were collected from typical locations in Ann Arbor, Michigan, and Indianapolis, Indiana. Some were reared in the laboratory. Microscopic preparations were made of adult specimens taken throughout the year, with a view to correlating histological conditions of the ovotestis with the seasonal activity observed. In order to trace the development of the gland juvenile specimens of different sizes were prepared. This series was graded from 0.6 mm., the size of individuals measured shortly after hatching, to 2.0 mm., the average adult size — the measurements representing the widest shell diameter of alcohol specimens.

The material was fixed in modified Bouin's solution, which de-

calcified the shell, so that it was easily removed. Normal butyl alcohol was used in the dehydration and infiltration of some of the specimens and dioxane for the rest. Serial sagittal sections gave the most favorable disposition of the organs for study. The material was sectioned for the most part at 8 or 10 microns, and stained with Heidenhain's iron hematoxylin without counterstain.

The small size was of some advantage for microscopic study in that a complete individual series could be accommodated on one or two slides, and the entire hermaphrodite gland could be studied *in situ*. In larger forms it must be removed and divided.

The figures were prepared from photomicrographs and from camera lucida drawings.

ANATOMY OF THE HERMAPHRODITE ORGANS

The hermaphrodite organs of *Vallonia*, as described by Steenburg (1918), include the hermaphrodite gland, the hermaphrodite canal, the seminal canal, which is continuous with the vas deferens and penis, the narrow oviduct and vagina, and the genital cloaca, which opens by way of the common genital orifice behind the right tentacle. The prostate and the albumen gland and other accessory structures are also described. We have mentioned above that both Steenburg (1918) and Watson (1919) found the penis and vas deferens lacking in many specimens. This observation was confirmed by the present study, since careful examination of sections failed to reveal anything resembling these structures.

The hermaphrodite gland, or ovotestis, is embedded in the lower portion of the upper division of the liver. Steenburg (1918) describes its form as follows: "The pyriform acini are united in three groups, not very distinct, comprising three or four acini each." A gonad of this description is of the "unsegregated" type as distinguished by Furrow (1937). The cysts containing both male and female germ cells join the hermaphrodite duct, which serves as both a sperm duct and an oviduct. This condition is found in *Helix*, *Physa*, *Lymnaea*, *Planorbis*, and *Polygyra*, as well as in *Vallonia*.

HISTOLOGY OF THE ADULT GLAND

Sagittal sections of mature animals collected during the active season show quite clearly the three groups of acini making up the ovotestis, as described by Steenburg (Pl. I, Fig. 1). The cortical

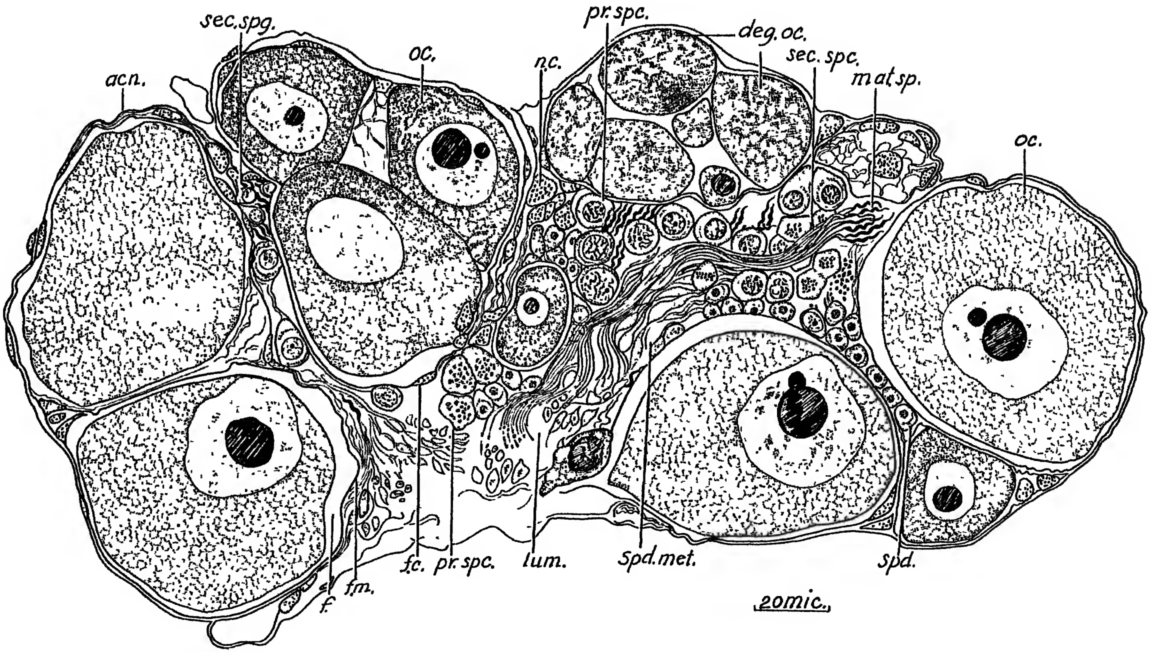

FIG. 1. Camera lucida study of mature gonad in individual collected in July. Abbreviations: *acn.*, acinus wall; *deg. oc.*, degenerating oöcytes; *f.*, follicle; *f. c.*, follicle cell; *f. m.*, follicular membrane; *lum.*, lumen; *mat. sp.*, mature spermatozoa; *n. c.*, nutritive cell; *oc.*, oöcytes; *pr. spc.*, primary spermatocytes; *sec. spc.*, secondary spermatocytes; *sec. spg.*, secondary spermatogonia; *spd.*, spermatids; *spd. met.*, spermatids in metamorphosis. (Reconstructed from three adjacent sections)

regions are crowded with large oöcytes protruding from the walls of the acini (text Fig. 1). These are covered with thin follicular membranes, in which at intervals isolated nuclei of various sizes appear. Some of the smaller nuclei are much flattened. The larger ones, of the nurse-cell type, are more rounded, and their chromatin has the characteristic appearance of coarse angular blocks. Cell outlines are difficult to distinguish. According to Gatenby (1919a) and Woldt (1932), the large "hyperchromatic" nurse cells apparently develop from smaller epithelial cells of more generalized type. Gatenby found all gradations between them.

It has been suggested that these nutritive or follicle cells, by building the follicular membranes, prevent self-fertilization; and again that they serve as supporting cells, holding the ova in position so that they remain advantageously situated with respect to the nutritive fluids of the body cavity, which must diffuse from the outside to the interior of the gland.

In *Vallonia*, as in *Helix* and other forms, it seems probable that additional nutritive material is contributed by degenerating oöcytes, which are very commonly found in the ovotestis. Some sections may show the whole contents of a cyst made up of these (text Fig. 1), or a cyst may contain one large developing oöcyte and several smaller degenerating ones.

Additional nutritive material may be contributed by spindle-shaped fragments of cytoplasm often observed in the neighborhood of mature spermatozoa and spermatids in various stages of metamorphosis (text Fig. 4p). It seems likely that this material, discarded during the process of metamorphosis, helps to form a nutritive fluid which fills the interior of the gland and bathes the cells.

The lumen of the active gland is occupied by male cells in various stages of maturation, especially in the medullary portion, where the acini converge toward the hermaphrodite duct. This seems to be the most active region in the production of new elements, for here small new oöcytes also appear in the germ wall, in proximity to the male cells in the lumen. From this position the small oöcytes apparently migrate, as they grow, into the deeper portions of the acini. Many of them exhibit an elongated, tapering form which suggests an ameboid migration, somewhat similar to that described for the germ cells of *Planorbis* by Merton (1930).

The male cells tend to occur in groups, although some isolated ones are scattered about, here and there. The cells composing each group are all in approximately the same stage of development, a condition noted in *Helix* by Demoll (1912) and others. Such groups have been called "cell nests," and each one has arisen, according to interpretation, from a single primary spermatogonium.

Fifteen to twenty large oöcytes, besides a number of smaller ones, have been counted in typical specimens collected in July. These quite fill up the acini and, together with the groups of male cells crowding the lumen, give the whole gland a relatively compact appearance.

Sections of material fixed during the dormant season, in January, for example, show the gland in a somewhat ragged form, with open spaces left by the discharge of cells during the previous season (Pl. II, Fig. 2). A number of large oöcytes may be left over, and some of medium size, but few if any small new ones are to be found. Male cells are few and scattered, not exhibiting the orderly arrangement in groups which is indicative of recent division. Throughout the gonad many of the cells appear shrunken and distorted, but others do not differ markedly from corresponding stages found during the active period. Conceivably they are in an arrested condition and might regain activity and function the following season.

Although egg laying did not take place in the out-of-door sites to any great extent until the middle of May, individuals collected early in March and April show evidence of considerable growth activity in the hermaphrodite gland, doubtless in response to warmer temperatures during a part of the day. In particular, the active medullary region is occupied by a considerable number of small oöcytes at the onset of their growth, and by early spermatocytes as well (Pl. II, Fig. 3).

Material fixed in the fall shows fewer cells and more open space (Pl. II, Fig. 4) than the summer material. Later growth and maturation stages are more conspicuous than earlier ones.

Animals reared or kept for some time in the laboratory under what might be regarded as optimum conditions are characterized in section by the same abundance and variety of growth and maturation stages as those collected during the active season out of doors.

THE DEVELOPING GLAND

The classic work of Ancel (1902) on *Helix pomatia* describes the genital rudiment as it appears within the mesoderm several days before hatching. At this early stage it is a quite solid mass of cells, which slowly elongates and ultimately fuses with the hermaphrodite canal. A lumen then appears which transforms the gonad into a hollow vesicle, united at one end with the hermaphrodite duct and expanded at the other. In Ancel's opinion, all the cells making up the genital gland are derived from elements of the primordial anlage. At no time do foreign elements penetrate into it. According to his observation, sperm cells were the first to differentiate, then nurse cells, and then egg cells, but Buresch (1911) describes these three elements as arising simultaneously from the germinal epithelium.

Pennypacker (1930) found both male and female germ cells in the ovotestis of *Polygyra appressa* from the 5-mm. stage on. These authors note that mature spermatozoa are present in the young gland of both *Helix* and *Polygyra* long before mature ova, and that the development of the male cells takes place in the lumen, whereas the female cells remain in the walls of the acini during their entire stay in the ovotestis.

The early development of the hermaphrodite gland of *Vallonia pulchella* presents striking similarities to that described by Ancel for *Helix*. In the present study the genital rudiment was first identified about the time of hatching. The stages representing the course of development are described and figured (Pl. III, Figs. 1–7). The time required to complete development varies somewhat with external conditions, so that size was regarded as a better descriptive criterion of the series than age.

The 0.6-mm. Stage (Pl. III, Fig. 1; Pl. IV, Fig. 1; text Fig. 2)

The newly hatched animal measures 0.5 to 0.6 mm. in diameter. It emerges well developed and active, with a whorl of its body shell completed. At this time the hermaphrodite gland is a small compact mass of dense, closely clustered cells, situated in the inner coil of the body. The cells are very small, scarcely more than 5 microns in diameter, and have proportionately large nuclei and very little cytoplasm. They are essentially alike in appearance, although varying somewhat in size. It is not possible at this stage to recognize

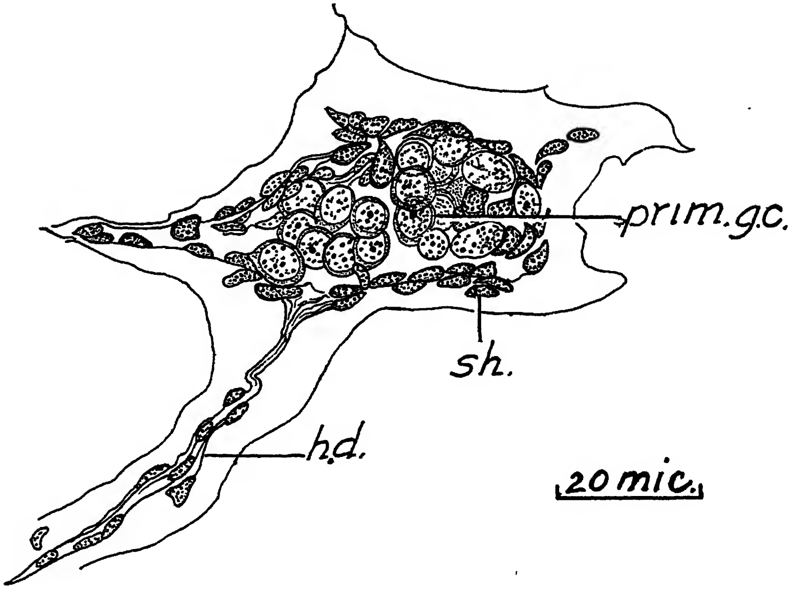

FIG. 2. Camera lucida study of immature undifferentiated gonad at time of hatching. Abbreviations: *h. d.*, hermaphrodite duct; *prim. g. c.*, primordial germ cells; *sh.*, sheath of gonad. (Reconstructed from two adjacent sections)

which cells will mature into male and which into female germ cells. In some preparations they appear grouped in a few small grapelike clusters, as if they had arisen by division from a still smaller number of cells of earlier origin. The whole group is invested with a sheath containing small darkly staining nuclei. Ventrally the genital rudiment tapers off into the very slender, slightly wavy hermaphrodite duct, which at this time also appears to be a solid rudiment. This stage reminds one of the first small mass of cells described by Ancel (1902) for *Helix*. Hsiao (1939) describes a similar undifferentiated early gonad for the marine snail *Limacina retroversa*.

The 0.9-mm. Stage (Pl. III, Fig. 2; Pl. IV, Fig. 2)

In animals measuring 0.9 mm. the massive arrangement of the gland persists, but cell differentiation is now initiated. At the periphery of the mass a few cells show the beginning of growth and are clearly recognizable as oöcytes because of the proportion of

cytoplasm to nucleus and the prominent double nucleoli, which are characteristic of oöcytes both large and small wherever found in the gland. At the center of the group are smaller cells, many with interphase nuclei, but a number in prophase and some with distinct chromosomes. These are the primary spermatogonia, and sometimes there are associated with them still smaller cells of similar appearance, the secondary spermatogonia. Thus the characteristic orientation of female cells toward the periphery and male cells in the interior becomes evident in the very young gland, in which no definite lumen is as yet formed. A few nurse-cell nuclei are irregularly disposed toward the outer portion of the cell group.

The 1.0-mm. Stage (Pl. III, Fig. 3; Pl. IV, Fig. 3; text Fig. 3)

In most preparations of 1.0-mm. animals or those a little larger there is a definite lumen in the hermaphrodite gland, so that it has the form of a simple undivided vesicle, which tapers below into the hermaphrodite duct. One is impressed with its similarity to the early gonad of *Helix* as described by Ancel. The older oöcytes are larger than those of previous stages, and small new ones occur in the portion of the gland nearest the hermaphrodite duct. As they grow they apparently migrate toward the deeper expanded portion of the germinal vesicle, in which region the largest ones are found. In the lumen are male cells in various stages. A number of ripe spermatozoa are included. Their early appearance in *Helix* and *Polygyra* has been noted.

There is evidence of an occasional penetration of these early maturing sperm cells into young oöcytes. At least some sections show bodies in the egg cytoplasm which are in every way similar to surrounding sperm heads, and at the periphery of these oöcytes are sperm heads which give the appearance of having just penetrated the surface by means of spiral movements (Pl. IV, Fig. 3; text Fig. 3). It is difficult to say what such an early impregnation may signify. In the slug *Arion empiricorum*, Lams (1910) has noted that oöcytes are regularly inseminated while still in the germ wall, and maturation and cleavage stages occur in the interior of the gland. Buchner (1914) describes a penetration of spermatozoa into the early oöcytes of the archiannelid *Saccocirrus*, the sperm being retained in the egg cytoplasm throughout the growth period and then taking part in an entirely normal fertilization.

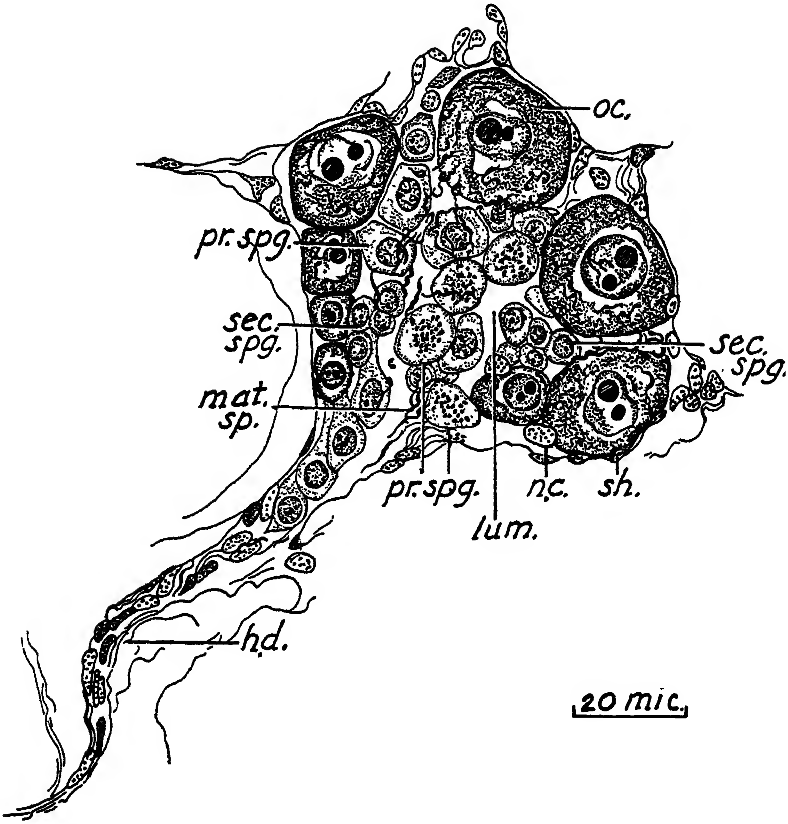

FIG. 3. Camera lucida study of immature gonad from 1.0-mm. individual, showing presence of mature spermatozoa and their penetration into young oöcytes. Abbreviations: *h. d.*, hermaphrodite duct; *lum.*, lumen of the gland; *mat. sp.*, mature spermatozoa; *n. c.*, nutritive cell; *oc.*, oöcyte; *pr. spg.*, primary spermatogonia, interphase and metaphase stages; *sec. spg.*, secondary spermatogonia; *sh.*, sheath. (Reconstructed from two adjacent sections)

In *Vallonia* it has not been possible to trace any definite sequence of events following early impregnation. It seems improbable that it can have any significance in fertilization; rather, the fate of these early penetrating spermatozoa is a rapid absorption. At times indefinite elongated bodies are seen in oöcytes of various sizes which have somewhat the appearance of sperm cells in process of dis-

integration, although other interpretations are possible. They are seldom found in full-grown oöcytes, and it seems likely that any penetration in early stages may be due to the follicular membranes not being well formed, and that when these are fully developed they make an effective barrier against insemination of the egg until after ovulation. I have never discovered any cleavage stages or even maturation spindles in oöcytes while they remained in the ovotestis. It seems clear that the definitive insemination resulting in fertilization does not occur until the female cells have become detached from the acinus walls.

The 1.3-mm. Stage (Pl. III, Fig. 4)

The principal changes noted in the 1.3-mm. stage are a widening and upward extension of the gland and the development of a more lobate form. There is also an increase in size of the oldest oöcytes as compared with those of earlier stages, and with the widening of the lumen the characteristic grouping of male cells in "cell nests" becomes apparent.

The 1.5-mm. Stage (Pl. III, Fig. 5)

In the 1.5-mm. stage a division into primary acini is indicated, accompanied by a further increase in size of the oöcytes and of the gland as a whole.

The 1.8-mm. Stage (Pl. III, Fig. 6)

In animals measuring 1.8 mm. there occur further enlargement and a subdivision of the gland into lobules, and the oöcytes approach the maximum size of those in the adult gland. New generations of smaller oöcytes continue to appear in the active medullary region. The lumen is almost completely filled with groups of developing male cells representing practically all stages of maturation.

The 2.0-mm. Stage (Pl. III, Fig. 7; Pl. IV, Fig. 4; text Fig. 1)

Two millimeters is the average adult size, and when the young animal reaches this diameter the ovotestis corresponds in structure to that already described for the active mature individual. Egg laying follows very shortly, as was observed in my previous study (Whitney, 1938), so that sections may show not only large oöcytes filling up the acini of the hermaphrodite gland but a fertilized egg in the outer genital passage, invested with albumen and shell and ready to be laid (Pl. I, Fig. 2).

MATURATION OF THE GERM CELLS

The maturation of the germ cells of Pulmonata and of other hermaphrodite mollusks has been the subject of a great amount of careful investigation. Since the present study does not deal with detailed observations of chromosome structure, or of the nebenkern, mitochondria, or other cytoplasmic inclusions, no attempt will be made to review this extensive literature in any detail. Most authors agree on the origin of male, female, and nutritive cells from an indifferent germinal epithelium. Both internal genic factors and external influences, such as proximity to nutritive sources, have been cited as sex-determining (Ancel, 1902; Buresch, 1911; Gatenby, 1917, 1918, 1919 a and b; Pennypacker, 1930).

Demoll (1912), Alexenko (1928), and Perrot (1930) have described heterochromosomes and have followed their course through spermatogenesis and oögenesis. The manner in which these operate to determine sex remains, however, somewhat hypothetical. A considerable section of the literature has to do with the production of atypical spermatozoa and abortive ova. This literature has been reviewed by Furrow (1935, 1937), who summarizes the chief theories concerning the significance of these abnormal forms. In some studies atypical spermatozoa have been found to effect a partial fertilization (Hyman, 1925; Portmann, 1930). By penetration or contact they seem to determine which eggs are destined to have a merely nutritive function. The usual fate of abnormal spermatozoa, however, is degeneration, and, on the whole, Furrow is inclined to regard them as the result of the interaction of two widely differing germinal tissues in the same gland. They represent a sort of rudimentary hermaphroditism which might be expected in forms intermediate between hermaphroditism and definite dioecism. This is found even in higher animals such as the frog, which in some instances shows a tendency to develop ovarian tissues in the testes. According to Ankel (1930), this labile sex condition would be expected to result in dimorphism of eggs as well as sperm, a dimorphism manifested by an inability of a certain number of eggs to develop. He points out that degenerating eggs are very common in prosobranch ovaries and sometimes serve as nutritive material.

In *Vallonia*, though there is some variety in the appearance of the cells and though unusual-looking spermatozoa have now and

then been found, no regular dimorphic series have been identified. If such dimorphism exists, the atypical forms must be quite rare. The majority of cells observed can be readily classified as belonging to the normal spermatogenetic series. Degenerating ova are common, as previously mentioned.

Spermatogenesis

The spermatogenesis of *Vallonia pulchella* is apparently typical. The stages are figured (text Figs. 4a–r), so that only their general features will be discussed.

Spermatogonia. — The first male cells identified in the interior of the young gland, while it is still in the form of a solid rudiment, are interpreted as being primary spermatogonia (text Figs. 4a–c). They are less easily found and identified in later stages, since they tend to occur singly and are not numerically prominent among the maturation stages. As compared with the indifferent cells of the earlier period, they are large, having a long diameter of 8–10 microns. They are frequently pedicellate, with the base directed toward the germinal epithelium or follicular membrane, and the wider portion of the cell, which contains the nucleus, facing the lumen. A number of them show mitotic figures, but chromosomes are difficult to count, owing to their small size and crowded condition. The counts made ranged from 36 to 38.

Smaller spermatogonia, 5–6 microns in diameter, are identified as secondary, being derived from the primary stages by mitotic divisions (Figs. 4d–e). Their chromatin is less finely dispersed, and they have a more rounded and compact appearance. They occur in groups suggesting recent divisions, whereas the primary spermatogonia, as stated above, are more likely to be found singly.

Primary spermatogonia are interpreted as originating from germinal epithelial cells, by a process of growth and differentiation. They are the first male cells shed into the lumen, where they give rise to secondary spermatogonia by repeated mitoses.

Spermatocytes. — Primary spermatocytes are numerous in mature glands during the active season. They are large cells 10–12 microns in diameter, and, like the spermatogonia, may be pedicellate. In section the cytoplasm forms a narrow border around the large nucleus. Typical preleptotene, leptotene, and bouquet stages are found (Figs. 4f–h). The tetrad stages (Fig. 4i) offer the best oppor-

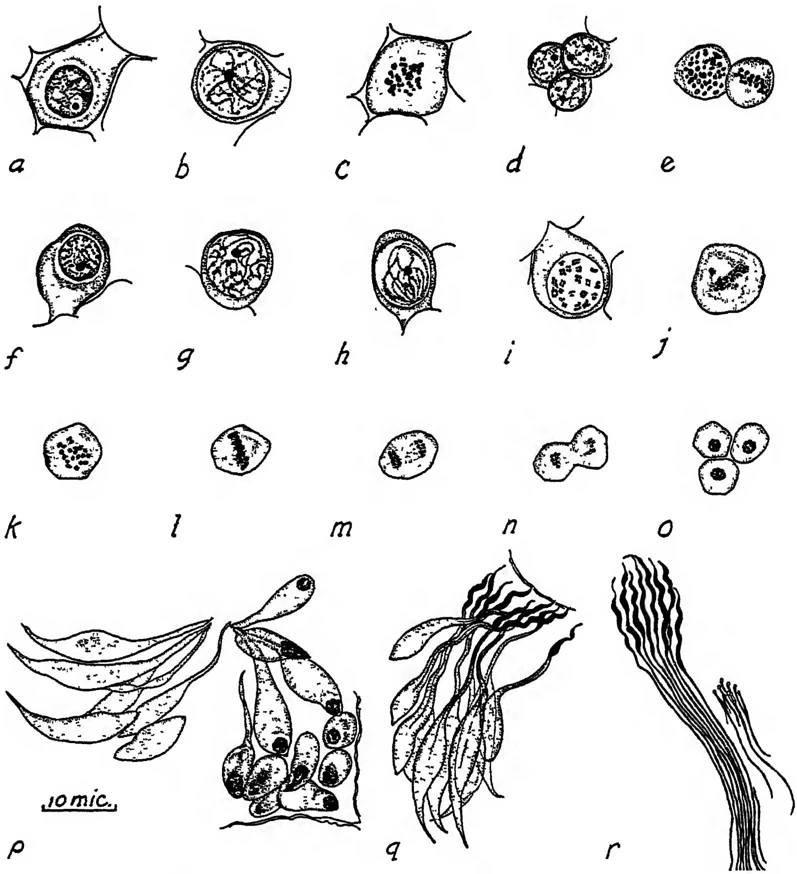

Fig. 4. Spermatogenesis: *a*, primary spermatogonium; *b*, primary spermatogonium in prophase; *c*, chromosome plate of primary spermatogonium, semiprofile view; *d*, group of secondary spermatogonia; *e*, chromosome plates of secondary spermatogonia; *f*, primary spermatocyte-preleptotene stage; *g*, leptotene stage; *h*, bouquet stage; *i*, tetrad stage; *j*, first maturation division, profile view; *k*, chromosome plate of secondary spermatocyte; *l*, second maturation division, profile view of metaphase; *m*, anaphase; *n*, telophase; *o*, spermatids; *p*, spermatids beginning metamorphosis; *q*, late stage of spermateliosis; *r*, group of mature sperm heads. (Selected from sections shown in Plate IV and text Figs. 1 and 3 and from other sections)

tunity for chromosome counts, since the chromosomes are better spaced in the large nucleus than in any other stage. On the average, about 20 tetrads have been counted.

Maturation divisions (Figs. 4j–n) evidently occur in rapid succession without the intervention of a resting stage, to judge from the infrequency with which these stages are encountered. These findings correspond with those of Demoll (1912) for *Helix*. Profiles of the two divisions are rather similar except for the differing sizes of the cells (Figs. 4j, l). The secondary spermatocytes measure 8–9 microns and show the small rounded chromosomes somewhat closely grouped in a dense homogeneous cytoplasm, without a nuclear membrane (Fig. 4k). A few chromosome counts were obtained. They ranged from 18 to 20.

Spermatids. — The spermatids (Figs. 4o–p) are small cells, 6–7 microns in diameter, and somewhat angular in outline as compared with cells of previous stages, probably owing to their being closely massed together in rather large groups often consisting of several dozen cells. They evidently remain in this stage for a considerable time, and are readily identified because of their uniform and characteristic appearance. They constitute a reserve from which a few mature spermatozoa are formed by metamorphosis from time to time.

Spermateliosis (Figs. 4p–r). — The cells are so small that little can be said of the details of metamorphosis. The spermatid elongates; the nucleus assumes a tapering form and comes to occupy one end. In some preparations an axial fiber is faintly visible. In later stages a spiral twisting of the sperm head occurs, a development described for other forms also (Byrnes, 1900; Woldt, 1932), and a spindle-shaped mass of cytoplasm is discarded from the tail. These discarded fragments apparently disintegrate, and may contribute to the nourishment of the maturing cells, as mentioned above.

Spermatozoa (Fig. 4r). — The mature spermatozoa, including the tail, may have a length of 60–70 microns. They usually occur in relatively small groups of about a dozen cells, but there are isolated ones also in various parts of the gland lumen. The tail is infrequently seen. It is probably lost before the sperm cell becomes functional, as authors have reported for other mollusks. We have already noted that spermatozoa may be present in the hermaphrodite glands of juvenile animals in which oöcytes have reached only a fraction of the maximum size.

Oögenesis

Origin of the female cells. — Ancel (1902) claims a unicellular origin for the egg cell of *Helix*. He expresses the view that each

female cell is formed directly by a process of growth and differentiation from a germinal epithelial cell, without a preliminary multiplication through oögonial divisions. To quote his account, "As soon as the female cell is recognizable . . . it is in the growth stage, — one cannot differentiate in the young gland of *Helix* a female cell that is not an oöcyte. The oöcyte arises directly from an epithelial cell to which one cannot give at any time the name primordial ovule or ovogonium." Essentially the same opinion is recorded by Buresch (1911), Gatenby (1917), and Pennypacker (1930). Although Pennypacker found certain cells in *Polygyra* which she was inclined to interpret as being oögonia, she could not identify them with certainty. Buresch points out that in general the function of the oögonial divisions is to increase the number of eggs and thereby the chances of survival, but in *Helix* he notes other protective features which make the production of a large number unnecessary: the eggs are enclosed in a hard shell; they are deposited deep in the earth; and the young emerge well developed, protected by the body shell.

In some mollusks oögonial divisions have been reported, but in *Vallonia* the situation evidently agrees with that in *Helix* and *Polygyra*, and the female cells are first recognized as oöcytes. No definite cells can be distinguished as true oögonia. Few eggs are produced, and various protective features associated with egg laying and development may be postulated as making a large number unnecessary, much as in the case of *Helix*.

Growth period. — The first recognizable oöcytes are found in the periphery of the young gonad while it is still in the early compact stage (Pl. IV, Fig. 2). They stand out from the spermatogonia because of the larger proportionate size of the cytosome to the nucleus, their elongated form suggestive of ameboid migration, and their prominent double nucleoli, the so-called amphinucleoli. One of these enlarges greatly during the growth period, the other much less. The larger of the nucleoli is regarded as being plasmatic; the smaller one, a true nuclear nucleolus.

The nucleus stains more lightly than the surrounding cytoplasm, and as growth progresses the nuclear chromatin, irregularly dispersed, tends to lose its staining properties to some degree and shows up as rather faint fluffy masses, similar to the condition described for *Polygyra* by Pennypacker (1930).

Full-grown oöcytes, as seen in their later position in the acinus

walls, have irregular polygonal forms because of the pressure of adjacent cells. They measure 70–75 microns in their longest diameter. The nucleus tends to have a rounded outline, but in some of the largest cells it may be quite irregular. This may indicate an approach to the breaking up in preparation for the maturation divisions. But I have never found any maturation spindles or cleavage stages while the female cells remained in the ovotestis of *Vallonia*, and a number of authors similarly record the absence of these (Byrnes, 1900; Larambergue, 1930; Pennypacker, 1930; Woldt, 1932). An exceptional case is that recorded by Lams (1910), who describes an intraovarian insemination in *Arion empiricorum*. He observed not only maturation divisions but segmenting eggs, morulae, and blastulae, in the interior of the gland.

Maturation divisions. — It seems evident that in *Vallonia*, as in the majority of the forms cited above, maturation divisions do not take place until after ovulation. The breaking up of the egg nucleus and the formation of the maturation spindle must be accompanied by a very rapid passage of the egg from the hermaphrodite gland into the outer genital passage. A number of authors record their failure to find ova in the hermaphrodite duct. In the present study maturation divisions have been observed only in eggs located in the outer passage, invested with albumen and shell, and ready to be laid. Such an egg is figured (text Fig. 5a) with what is interpreted as a polar view of the first maturation spindle, showing large asters and 32 chromosomes. The diploid number indicated by other counts is nearer 40. In this cell it may be that only part of the chromosomes have separated or that some are irregularly crowded together and difficult to distinguish.

Figure 5b shows an egg similarly situated in the uterus, with the second maturation division almost completed. The first polar body has migrated a short distance into the albumen. The second polar body still adheres to the surface of the egg, being held by remnants of spindle fibers. The egg chromosomes form a straggling group, not yet reorganized into the female pronucleus, and the sperm head, still small and compact in a little clear area near the periphery of the egg, has not yet begun its development into a male pronucleus. Indications are that the polar bodies have been given off in rapid succession, since the chromosomes of the first polar body are still clear and distinct. Counts of 17 and 18 have been made in several

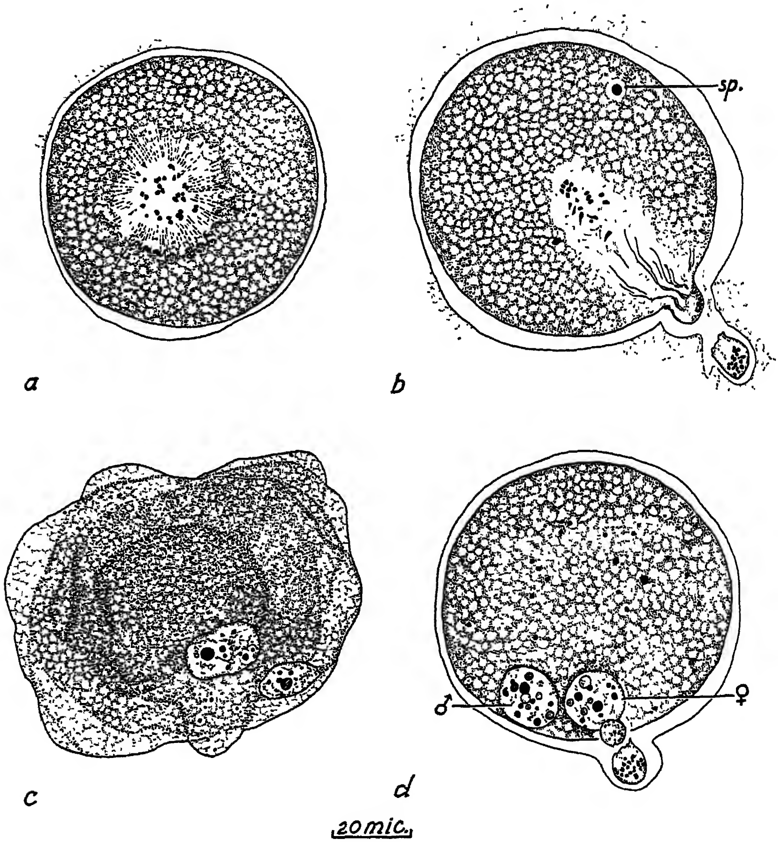

Fig. 5. Fertilized eggs found in outer genital passage: *a*, first maturation spindle, polar view of metaphasic chromosome plate; *b*, second maturation division — two polar bodies, egg chromosomes, and head of spermatozoon (*sp.*) shown — both *a* and *b* surrounded with albumen layer and shell; *c*, *d*, two fertilized eggs found in the same individual — *c* in the region of the albumen gland but lacking the albumen layer, *d* with albumen and shell — both showing male and female pronuclei. (All reconstructed from two or more adjacent sections)

instances. The chromosomes of the second polar body are smaller and less distinct. Few examples were obtained which were favorable for the counting of egg chromosomes. Those in Figure 5b number about 20.

INSEMINATION

The intraovarian insemination noted in *Arion empiricorum* by Lams (1910) is exceptional among gastropods. In most studies authors have found insemination delayed until after oöcytes have left the acini. In *Vallonia* I have not observed actual penetration of spermatozoa, except possibly into early oöcytes (Pl. IV, Fig. 3), but it seems most reasonable to suppose that the definitive insemination occurs as the ova leave the acinus wall and traverse the medullary portion of the ovotestis on their way into the hermaphrodite duct. It is here, in the lumen of this medullary region, that male cells in all stages, including ripe spermatozoa, are abundant during the active season, and even a very rapid passage through this part of the gland would afford ample opportunity for insemination. Monospermy is evidently the rule. I have found no supernumerary spermatozoa in the uterine eggs or in the albumen surrounding them.

FERTILIZATION

Good descriptions of fertilization processes in pulmonates have been contributed by Mark (1881) for *Limax campestris*, Garnault (1888–89) for *Helix aspersa* and *Arion empiricorum*, Byrnes (1900) and Linville (1900) for *Limax* species, Lams (1910) for *Arion empiricorum*, Crabb (1927) for *Lymnaea stagnalis appressa*, Larambergue (1930) for *Bullinus contortus*, and Perrot (1937) for *Helix pomatia*. There is a general similarity in these accounts. In the study of *Vallonia* it has not been possible to assemble a complete series of stages showing progressive steps in the development of the two pronuclei. The fact that eggs are deposited singly and at varying time intervals makes the obtaining of favorable stages a rather fortuitous matter. In only one instance have two eggs been found outside the hermaphrodite gland in the same individual. The first, enclosed in albumen and shell, occupies the lower passage (Fig. 5d). The second is farther back, in the region of the albumen gland but still lacking the albumen layer, and has an irregular form (Fig. 5c), which recalls a suggestion of Ikeda (1937) that ova make their way out of the hermaphrodite gland by means of ameboid movements. It has well-developed male and female pronuclei, like its predecessor, so that there is apparently no strict correlation between the progress

of maturation and fertilization and the level at which the ovum is found.

Such stages as have been obtained indicate that fertilization processes in *Vallonia* follow in a quite regular manner those of other pulmonates referred to above. There is only one spermatozoon in fertilized eggs; it appears first as a small, compact sperm head (Fig. 5b), but later transforms into a male pronucleus (Figs. 5c–d). The majority of the fertilized eggs in the uterine passage present in section an appearance like that of Figure 5d. They are invested with a thick albumen layer and shell, and are spherical, possibly because of suspension in the liquid medium, and also in part because of cortical changes accompanying fertilization. They measure 70–75 microns in diameter, which is the approximate size of the largest oöcytes while still in the hermaphrodite gland. This indicates that no growth takes place between the gland and the uterus. The cytoplasm is vesicular in appearance and contains small spherical yolk granules which stain black with iron hematoxylin.

The male and female pronuclei are typically in close juxtaposition at the animal pole. The male pronucleus in some preparations is slightly larger than the female and slightly elongated. The female pronucleus may be identified by the proximity of the two polar bodies. In both pronuclei the chromatin is in large, rounded, nucleoli-like masses, with smaller granules interspersed. This appearance must be quite characteristic, since it is noted repeatedly in the studies mentioned above.

In a few individuals cleavage has been found to occur while the egg is still in the oviduct. This may indicate an incipient tendency toward ovoviviparity. The eggs are retained in oviducts for varying periods, so that successive cleavages may take place. One egg fixed with the parent animal just as it was being laid shows indications of gastrulation. Others fixed soon after deposition are still in morula and blastula stages.

The evidence of typical chromosome reduction, the regular appearance of two polar bodies as well as two pronuclei, and the similarity of the stages studied to normal stages described for other pulmonates, together with the absence of the vas deferens and failure to observe copulation, all indicate that self-fertilization is the normal and usual process of reproduction in *Vallonia*.

DISCUSSION

One is impressed with the similarity of conditions in *Vallonia* to those of other Pulmonata, both in general and as regards many details. Specializations are noted, however, some of which at least seem to be due to restrictions of small size and others to habit and habitat. The large size of the eggs in proportion to that of the animal, their reduction in number, and protective features insuring juvenile survival are very striking. The eggs must be laid singly because of the small size of the animal, and egg laying is dependent on temperature and moisture. All land animals have to cope with problems of desiccation and extremes of temperature, and this is particularly true of a surface-living form such as *Vallonia*, which does not burrow to any extent, as does *Helix*, for example. These limiting factors are offset by the protracted breeding season (eggs have been collected out of doors from May to October) and by the readiness with which they are deposited whenever favorable conditions present themselves. Such conditions evidently induce a general activity of the germ gland, with the result that male and female cells in various stages of maturation are to be found in it at practically all times, although in an arrested condition during cold and dry periods. It is thus possible to bring some of them to maturity very quickly, as witness the readiness with which eggs are deposited in the laboratory by specimens brought in during the winter. Reproduction is evidently not complicated by alternating male and female phases or any such cyclical condition. Periods of drought and low temperature are to be regarded as enforced seasons of reproductive cessation rather than any functional break in the process.

The absence of male ducts, making self-fertilization obligatory, represents a further simplification both structurally and functionally and, as has been suggested in other studies, may have favored survival and propagation. I have found populations of *Vallonia* year after year in the same restricted area and at times very congested. This I attribute to the limited migratory powers of the animal and to artificially favorable moisture conditions around dwellings which make possible more continuous egg laying and a consequent piling up of populations.

Human agencies also multiply opportunities for accidental dispersal which would be advantageous to a slow-moving form, and

the power of self-fertilization would enable any isolated individual transported into a new region by such means to start a new colony.

SUMMARY

This paper presents histological studies of the hermaphrodite gland of *Vallonia pulchella* Müll. as correlated with the life cycle and habits of the animal. The following features are brought out:

1. The ovotestis of the mature animal has the form of an acinous or digitate structure, with a number of cysts opening into a common lumen and joining the hermaphrodite duct, as is typical of many hermaphrodite mollusks. The efferent ducts have not been studied in detail, but the absence of the vas deferens was noted in sections, in agreement with the findings of previous authors. The absence of copulation is thus explained, and also the fact that fertile eggs are laid as freely by isolated individuals as by those in mass cultures.

2. The microscopic features of the gland differ according to the seasonal activity. Material fixed during the active summer season shows all stages of maturation; dormant winter specimens indicate an arrested condition of the gland, whereas spring and fall material exhibits intermediate conditions. Both male and female cells, however, are present during all seasons. There is no evidence of an alternation of male and female phases or of any cyclical condition other than the enforced cessation of reproductive activity during cold and dry periods.

3. The ovotestis develops from a compact cellular body, which was first distinguished at about the time of hatching and which is composed of indifferent germ cells. It later assumes the form of a single hollow vesicle, which subsequently takes on a lobate structure and becomes subdivided into the acini composing the adult gonad. Accompanying this development is a differentiation of male, female, and nutritive (or follicle) cells from the indifferent cells of the early gonad. They continue to arise from time to time in adult life, whenever conditions are favorable.

4. Male cells, which are first identified as primary spermatogonia, undergo their maturation and development in the lumen of the ovotestis. Female cells, first identified as oöcytes, develop in the walls of the acini, held in place by follicular membranes produced by follicle and nurse cells. The medullary portion of the gland is

the most active in the production of new elements. There is apparently a migration of small oöcytes formed in this region into the acini, where the remainder of their growth period is spent.

5. There are mature spermatozoa in the gland at an early stage, when the animal is about half grown; full-grown oöcytes do not occur until adult size is reached, at which time egg laying begins. There is evidence of some penetration of young oöcytes by spermatozoa, but such spermatozoa apparently disintegrate and do not result in fertilization.

6. Maturation divisions and effective insemination of the eggs do not occur until after they leave the acinus wall.

7. Usually only one fertilized egg is found in the uterus at any one time, since the small size of *Vallonia* prevents the laying of more. Monospermy occurs, which leads to the formation of a typical male pronucleus.

8. Two polar bodies are regularly given off, either shortly before or after the egg becomes invested with albumen and a calcareous shell, and a female pronucleus develops along with the male pronucleus in a typical manner. Cleavage may begin before the egg is laid.

9. Chromosomal counts made in spermatogonia, primary spermatocytes, secondary spermatocytes, first polocytes, and eggs give a haploid number of 18 to 20.

10. Histological evidence from this study, including the presence of mature sperm and eggs in the same acini at practically all times, the absence of the vas deferens, typical synapsis and chromosome reduction, the formation of two polar bodies and the development of two pronuclei, supports previous studies in establishing self-fertilization as the normal method of reproduction in *Vallonia pulchella*.

11. In general, reproductive conditions are effectively adjusted to the small size of the animal and to environmental factors, and are apparently favorable to its distribution and survival.

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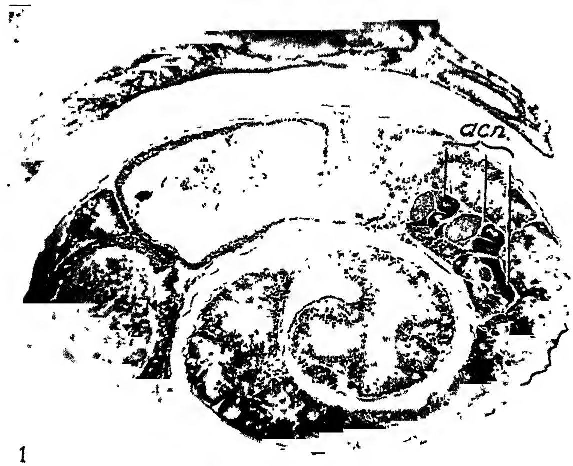
EXPLANATION OF PLATE I

Abbreviations: *acn.*, acini; *al.*, albumen of egg; *al. gl.*, albumen gland; *fert. egg*, fertilized egg; *ut.*, uterus

Fig. 1. Sagittal section through mature *Vallonia pulchella*, showing the position of the hermaphrodite gland and the three groups of acini composing it

Fig. 2. Sagittal section of mature *Vallonia pulchella*, showing a fertilized egg in the uterus, ready to be laid



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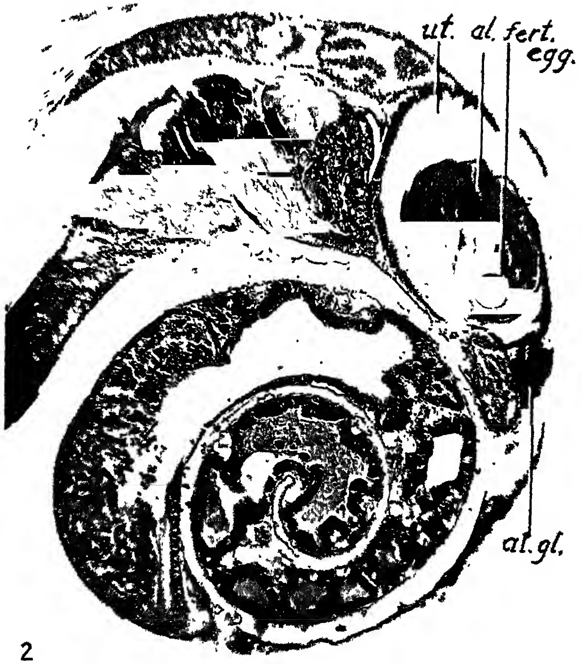

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EXPLANATION OF PLATE II

Conditions of the hermaphrodite gland at different seasons of the year

Abbreviations: *bouq.*, bouquet stage; *deg. oc.*, degenerating oöcytes; *f.*, follicle; *f. c.*, follicle cells; *f. m.*, follicular membrane; *lum.*, lumen; *mat. sp.*, mature spermatozoa; *oc.*, oöcytes; *pr. spc.*, primary spermatocytes; *spd.*, spermatids; *spd. met.*, spermatids in metamorphosis

FIG. 1. Active medullary portion of gland in individual collected in July

FIG. 2. Portion of gland in dormant individual collected during January

FIGS. 3–4. Portions of the glands in individuals collected in April and October, respectively


oc.
deg. oc.
bouq-
oc.
spd.
met.
spd.
1
mat.
sp.
zum.
oc.
f.
2
mat. sp.
zum.
pr. spc.
oc.
3
spd
oc.
mat.sp.
oc.
4

EXPLANATION OF PLATE III

Series showing development of the hermaphrodite gland from the time of hatching up to and including adult size. Stages: Fig. 1, 0.6 mm.; Fig. 2, 0.9 mm.; Fig. 3, 1.0 mm.; Fig. 4, 1.3 mm.; Fig. 5, 1.5 mm.; Fig. 6, 1.8 mm.; Fig. 7, 2.0 mm. Measurements represent the widest shell diameter of the alcohol specimens


1
2
3
4
5
6
7

EXPLANATION OF PLATE IV

Oil-immersion studies of developmental stages

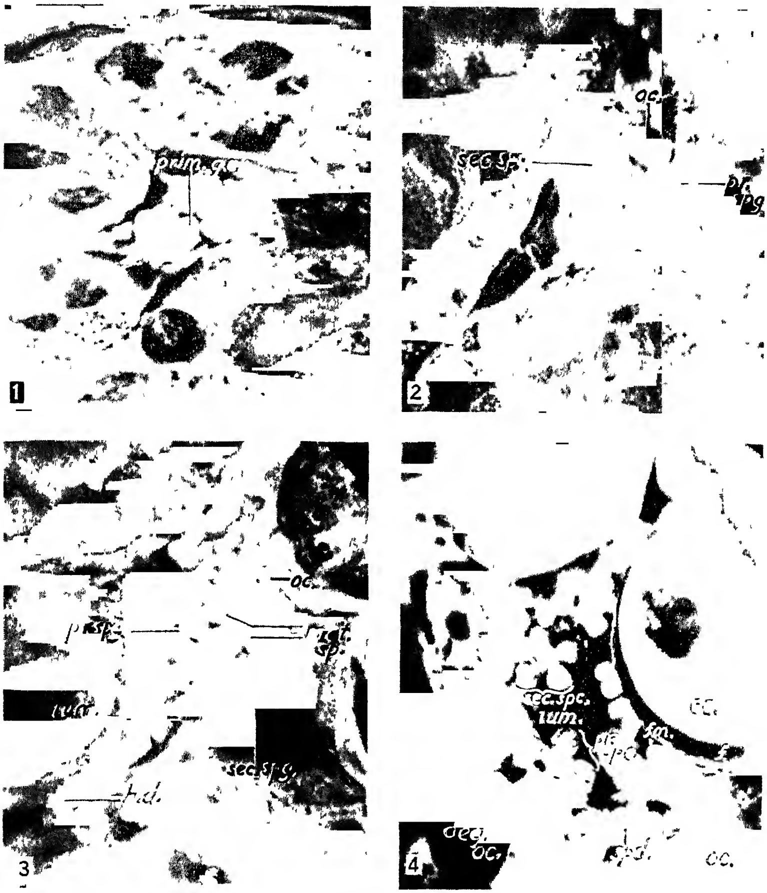
Abbreviations: *deg. oc.*, degenerating oöcytes; *f.*, follicle; *f. m.*, follicular membrane; *h. d.*, hermaphrodite duct; *lum.*, lumen; *mat. sp.*, mature spermatozoa; *oc.*, oöcytes; *prim. g. c.*, primordial germ cells; *pr. spc.*, primary spermatocytes; *pr. spg.*, primary spermatogonia; *sec. spc.*, secondary spermatocytes; *sec. spg.*, secondary spermatogonia; *spd.*, spermatids

FIG. 1. Undifferentiated early gonad shortly after hatching

FIG. 2. Beginning of differentiation, as seen in the 0.9-mm. individual (early oöcytes at the periphery; early maturation stages of male cells in the interior)

FIG. 3. Further differentiation as seen in a half-grown (1.0-mm.) snail; ripe sperm present, some penetrating into the young oöcytes

FIG. 4. Portion of mature gonad, showing full-grown and smaller oöcytes and male cells in various stages of maturation


1
prim. gc.
2
oc.
sec. sp.
pr. spg
3
oc.
sec. spg.
h.d.
4
sec. spc.
lum.
sm.
oc.
deg. oc.
oc.

A SERIES OF LATERAL ORGANS FOUND IN EMBRYOS OF THE SNAPPING TURTLE (*CHELYDRA SERPENTINA*)

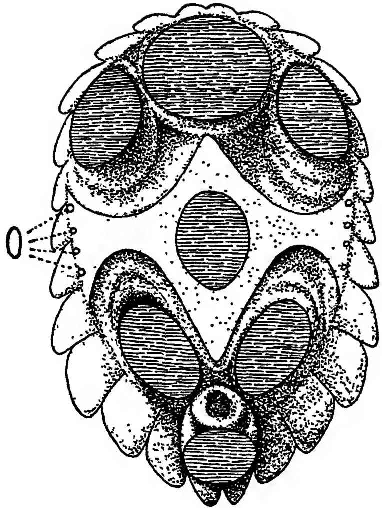
RAINER ZANGERL

PECULIAR organs serially arranged were noticed by the author along the lateral edges of the plastron in embryos of the snapping turtle *Chelydra serpentina.*[1] There are four in a row on either side of the body (Fig. 1). They are of such unusual histological structure that their morphological nature is difficult to determine. Each consists of an egg-shaped belly part, which lies within the subdermal mesenchyme, and a duct, which connects the belly portion with the outside of the embryo. Their shape varies slightly, but their chief construction appears identical in all specimens so far observed.

Histologically the belly of each organ is composed of two distinct parts: a cavity which represents the enlarged end region of the outleading duct and a comparatively heavy individual muscle, which encloses the whole end portion of the tube (Pl. I, Figs. 1–2). The entire organ is covered with a tough connective-tissue sheath. In addition, there is a layer of loose supporting tissue between the muscles and the end piece of the duct.

The tubular part of these organs is lined by stratified columnar epithelium which, at the distal end of the tube, goes over into the epidermis of the skin. The proximal end of the tube is blind and enlarged, and thus forms a terminal cavity. Some of the epithelial cells in this region (and also in the duct) seem to have freed themselves from their epithelial basis and appear within the lumen of the epithelial ingrowth. These cells are irregular in shape, but it is hard to decide whether they carry protoplasmic processes or whether the structures observed are due to a shrinkage of the cell bodies. True

[1] The writer is greatly indebted to Mr. H. Seton, of the Agassiz Museum at Harvard University, for a number of snapping-turtle embryos used for this investigation. They belonged to one litter, and their average size was about 20 millimeters carapace length.



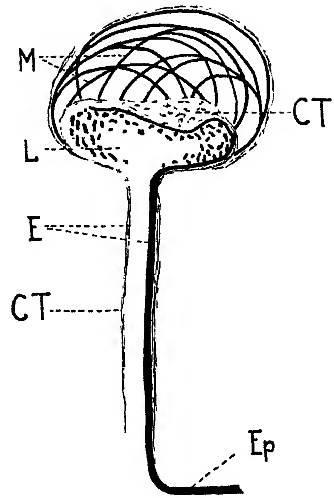


FIG. 1 FIG. 2

FIG. 1. Embryo of *Chelydra serpentina* (carapace length about 20 mm.) seen from the ventral side. The head, feet, and tail are cut off

FIG. 2. Diagrammatical drawing of an organ in cross section

Explanation of abbreviations: CT, connective-tissue sheath enclosing the organ and separating the end portion of the tube from the muscle; E, epithelium of the tube region; Ep, epidermis of the skin; L, lumen of the end piece of the duct; M, muscle bundles, with the distribution and the course of a few of them indicated; O, location of the organs in the embryo

cilia could not be found in the tube or in the blind end region. The question whether the cells lying within the lumen of this epidermal invagination have lost their normal epithelial connection because of maceration in the fixation fluid (the specimens were kept in formalin) can be answered in the negative with some certainty. There are no other places in the sections where a clear dislocation of cells due to maceration might have occurred. Furthermore, the epithelium lining the cavity and the duct appears in good contact; there are but very few spaces to be seen where cells might have dropped out (Pl. I, Fig. 1).

Around the enlarged end region of the epithelial tube is a layer of loose connective tissue, the thickness of which varies in different places. It may be just a thin sheath or, especially on the dorsal surface of the blind tube end, a thick cushion (Pl. I, Fig. 1). It

seems to be the place of origin and insertion of the relatively large muscle coat which forms the major portion of the belly part of the organ. The muscle cells are spindle-shaped and have a clear longitudinal striation. Not all the muscle cells run parallel, but the vast majority of them are transversally arranged. The course of the muscle-cell bundles is rather complicated. A few of them are drawn in Figure 2 to show their origins and insertions as well as their relationship to each other.

The organs are innervated by branches of the regionally corresponding spinal nerves which enter the belly portions at their anterior ends. Whether or not the nerves which innervate the organs carry sensory fibers besides motor ones has not been determined. In front of each organ the spinal nerve divides into two branches, one of which enters the organ; the other finds its way into the dermis.

A number of capillaries can be noticed throughout the muscle and connective-tissue region. Many white blood corpuscles occur, primarily along the peripheral edge of the muscle. They are ameboid in shape and have highly granulated nuclei. Similar cells are found in enormous quantities in the liver.

The unusual structure and location of these organs leave doubt as to their morphological and physiological nature. They might be glands, but the epithelium in the end region of the tube is not typically glandular and, furthermore, the presence of a heavy muscle belly around the end piece of a gland would be a unique feature. The structures might be sense organs of some kind. In view of their location, along the lateral edge of the body, one might think them to be organs of the lateral line system. There are no such organs known in Amniota, however. This interpretation becomes unsatisfactory also because of the association of muscles with these structures. A definite conclusion concerning the real nature of the organs can hardly be arrived at until new material for further study is available.

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PLATE I

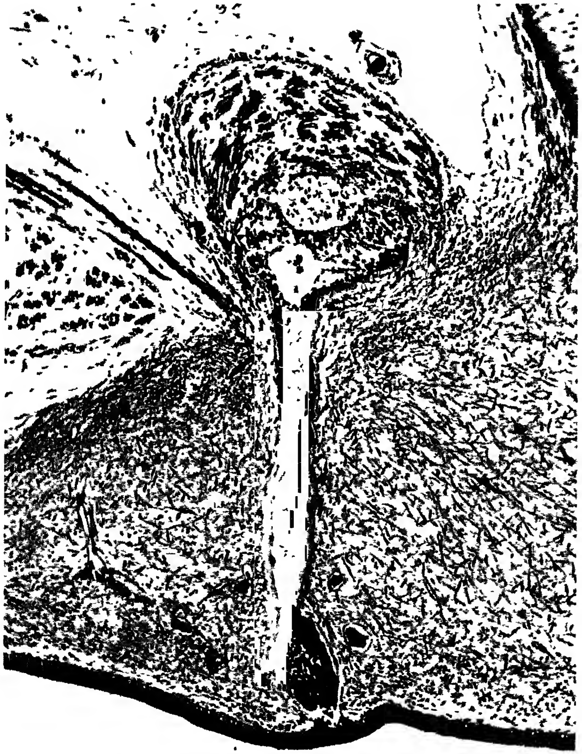


Fig. 1

Fig. 2

Microphotographs of lateral organs in embryos of the snapping turtle: cross section (left); longitudinal section as seen in a parasagittal section through the embryo (right)

GEOGRAPHY

A STUDY OF SETTLEMENT AND LAND USE IN LIVINGSTON COUNTY, MICHIGAN

W. BRUCE DICK †

Part I. House Types and Settlement

THE settlement of Livingston County, which took place about 1830, is representative of that of most of the southern counties of Michigan (Fig. 1). It was believed that a study of its settlement and of the origin of the immigrants would provide a better understanding of current land problems.

ROUTES OF MIGRATION

This investigation starts with the origin and migration of the settlers. Information concerning the locations of most immigrants' homes was found in old histories, plat books, albums, and the "tract book" containing some of the early Detroit Land Office records. The date and location of each settlement from the beginning to 1839 was secured from the tract-book records especially.

Most of Livingston County's early immigrants came from New York State (Figs. 2–3), particularly from the Genesee Valley counties. A few were from the New England States, New Jersey, Pennsylvania, and Ohio. Each dot on Figure 3 represents one family, an individual who arrived in advance of his family, or a bachelor. The dots were located on the county map with reference to the village names, if they were available, or were distributed at random. A few immigrants who came from Europe directly have not been represented on the map, but there were not enough of them to affect greatly the distribution of the origin of settlers as shown.

There were three main routes which the early settlers of Livingston County used in the fourth decade of the nineteenth century. De-

† Editors' Note — The untimely death of Mr. Dick on October 28, 1939, occurred while he was engaged in writing a report on a study of Livingston County, Michigan, as a part of his work for the doctor's degree in geography at the University of Michigan. His notes have been collected and the present account edited by Professor Stanley D. Dodge and Mr. Stanton J. Ware.

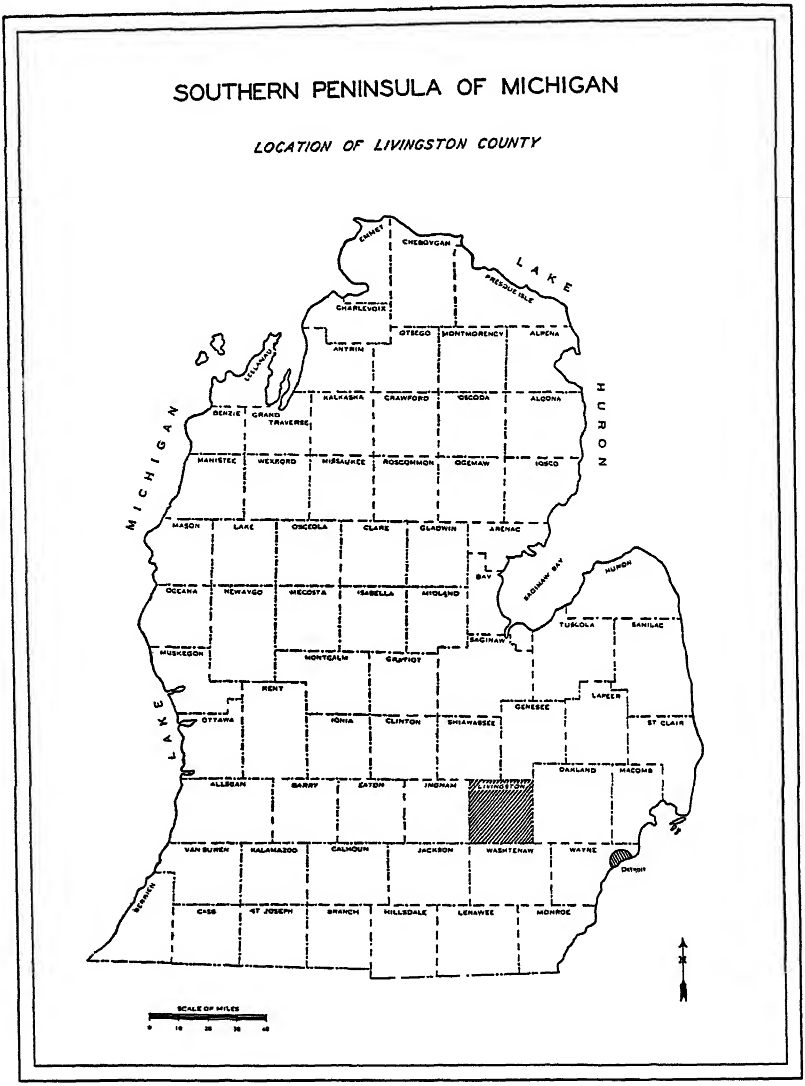


Fig. 1

pendable information on the exact position of towns through which the routes passed is not available, but we have records of a Canadian route from Buffalo to Detroit, a Lake Erie water route, and a south-

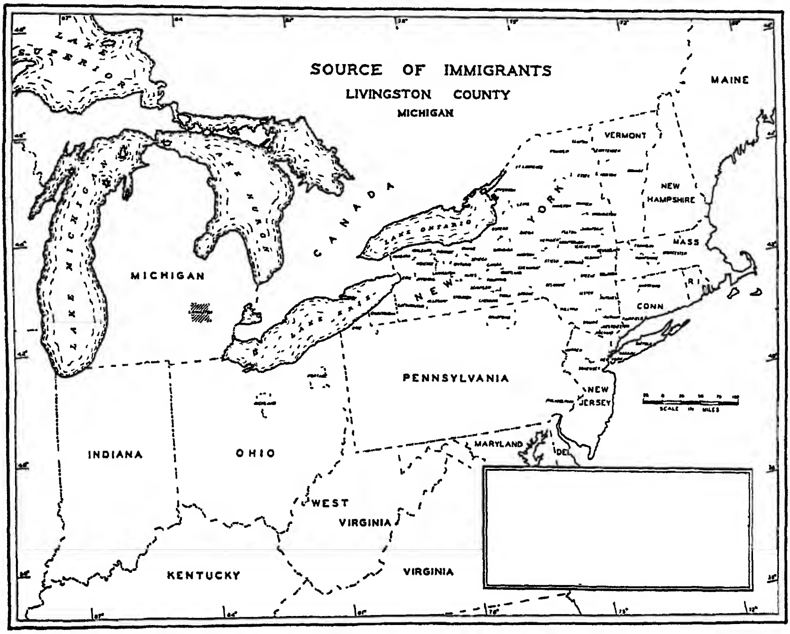


Fig. 2

ern overland route, which followed closely the south shore of Lake Erie. Historical sketches and records of the local Pioneer Society indicate that the water route was the one most frequently used. Overland travel was by oxcart or horse or on foot. It usually took one or two months to make the journey overland with horses, and nine or ten days by water.

Immigration focused on Detroit, the seat of the Government Land Office. In the period when Livingston County received its first influx of settlers Detroit had already had a century and a quarter of existence. In 1830 its inhabitants numbered 2,222, and it was a principal commercial center of Michigan, ranking next to the headquarters of the fur trade on Mackinac Island. Before the time of Pontiac, Indian trails had converged on the site of Detroit, and as settlement proceeded it became the chief point from which immigrants entered the unsettled lands of southern Michigan. The Government Land Office in Detroit was the point of origin of trails leading into the wilderness.

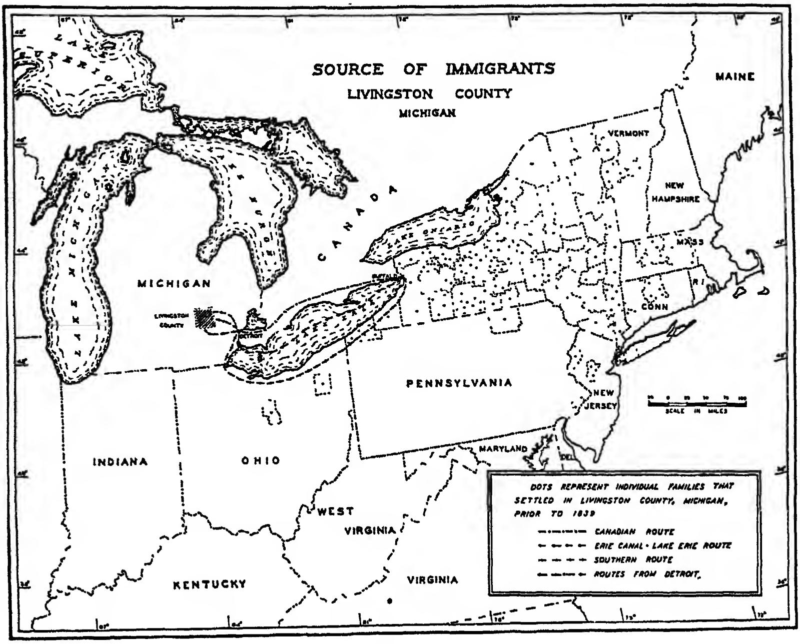


FIG. 3

From Detroit land seekers set out to view the new territory and to select pieces of property according to individual fancy. Early accounts of Michigan stated that the climate was generally milder than that of corresponding latitudes on the Atlantic Coast. The qualities of the soil were described in the most enthusiastic terms in nonofficial reports. Farmers were easily led to overrate the agricultural possibilities of southern Michigan so far as climate and soil were concerned, for the soils are not more fertile than the average in forested regions, nor is the climate so mild as early reports pictured it. The majority of the settlers came with the idea of founding homes and of supporting themselves by farming. Most of those who engaged in trades and public services arrived after the population had become large enough to justify them in establishing themselves in the new settlements. Land speculators, with their unethical practices, were rampant, but we are here concerned only with people who actually settled in Livingston County.

Settlement was facilitated by Indian trails; the chief ones con-

verged on the straits at Detroit and in turn afforded convenient routes into the territory of southeastern Michigan. The Grand River Trail was an important route from Detroit to Livingston County; it is the middle of three routes running west from Detroit (see Fig. 3). The other two are Indian trails of less importance, but some of the immigrants traveled over them.

The region which is now Livingston County received its earliest settlements in the southern and southeastern sections. Since Detroit was the seat of the land office for Michigan, immigrants seeking new lands in the interior frequently traveled from there by way of Ann Arbor. This route led them ultimately to the southern part of the county. The route from Detroit by way of Royal Oak, Birmingham, and Walled Lake was used at a later date.

Colonel Solomon Peterson was the first white person who made a permanent residence in this county. He settled on Portage Creek in Putnam Township in 1828. Stephen Lee and Benjamin Curtis established homes in Green Oak Township in 1830. Other settlers arrived at Hamburg in 1831 and at Brighton in 1832. Unadilla, the last of the southern string of townships to be settled, received Eli Ruggles as its first resident in 1833. The years 1833, 1834, and 1835 saw at least one permanent settler in each of the remaining townships.

Most of these early settlers were from New York State or southern New England. They were generally the younger members of successful farming families, and they wished to make homes for themselves and to own farms as productive as those of their parents and relatives. Many of them came to Detroit by boat by way of the Erie Canal and Lake Erie, and then continued their journey to Livingston County by oxcart or on horseback. Like any other pioneer people, they had a rough time, but settlement was not so difficult as it had been for their parents and grandparents in New England. The Indians here were quite peaceful after the Indian Wars, and the county abounded in fish and game. There were years of privation, however. In 1876 the Honorable W. A. Clark stated before the Pioneer Society that "Families to my knowledge in 1837–38 lived for days through necessity on boiled acorns, with fish cooked and eaten without salt or fat of any kind. Provisions were then often held at fabulous prices; . . . beef, pork and flour had to be brought from Detroit, at a cost of from one to two dollars per hundred to Brighton, forty miles. It was not so very high, either, for the round

trip, with an energetic teamster and an enterprising team, usually took three to four days, if not longer." [1]

In the year 1838 crop yields were plentiful, and after the harvest wheat fell to a low price. It was so abundant that it sold at less than three shillings a bushel. Cattle prices also dropped.

The marsh grasses along stream banks and upland grasses in the openings afforded very fine natural pastures for cattle. They also provided subsistence for the first winter or two until land could be cleared for the planting of timothy, clover, and alfalfa.

From the records of the old tract book in the office of the register of deeds at Howell a series of dot maps showing the spread of settlement has been prepared (Fig. 4). Each includes the additional settlements which took place in the years indicated. Every dot represents an individual or a family settlement, and as nearly as possible each one has been placed according to the location of the property settled upon. The first settlement, shown by the heavy dot, occurred in 1828 in Putnam Township, near the site of the present village of Pinckney. There was no recorded settlement in 1829, so far as could be determined. By 1839 the population had spread over the entire county, and the settlement of new land was mainly over.

The map of Howell Township may be taken as an illustration of the way in which the others were constructed. The *History of Livingston County, Michigan* (see note 1) gives a list of people by sections of townships; it includes only those who took up Government land, but it tells where they came from and gives the dates of their settlement. A tract book at the register's office in Howell furnished this information for the authors of the *History*. The land entries for Howell Township were plotted on a map of ownership and were compared with one of 1935. It was thought that some of the present owners of the same name might be descendants of the early settlers, but only one family in Howell, the McPhersons, has remained. The first land entry in Howell was made by Orman Coe, of Genesee County, New York, on May 20, 1833. He took up land on the eastern half of the southwest quarter of Section 27. Settlement was very slow at first, but about 1836 and 1840 it became rapid. By 1860 all the Government land in the township had been taken.

[1] Ellis, Franklin, *History of Livingston County, Michigan,* p. 22. Philadelphia, 1880.

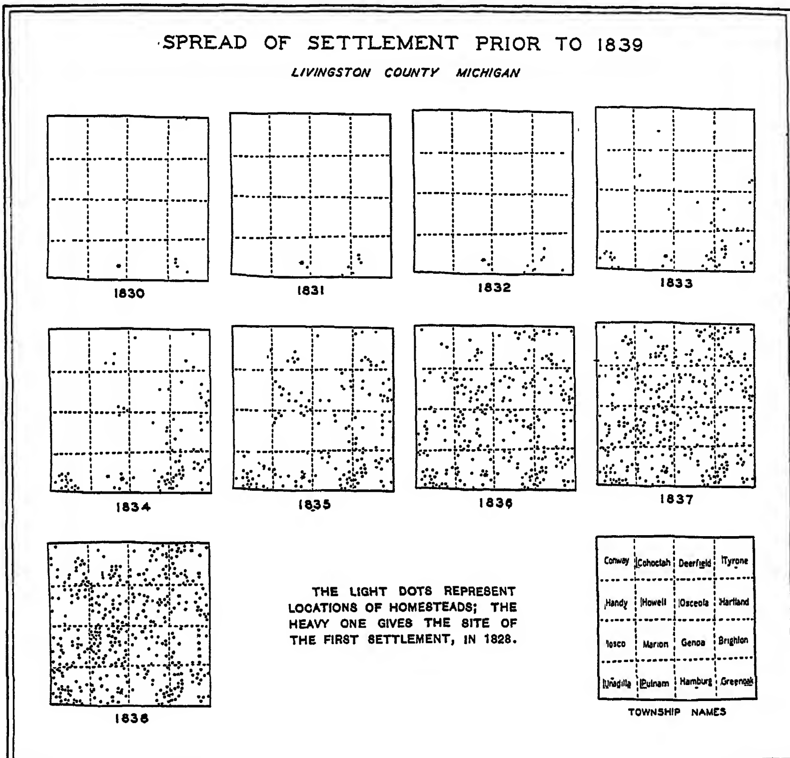


FIG. 4

ADVANCE OF SETTLEMENT

The isochronic map (Fig. 5) shows that the settlement of Livingston County made most rapid progress along an axis which corresponds to the Grand River Trail, mentioned earlier as the principal route used by the settlers journeying from Detroit to the new lands in Livingston County. Today it is the main highway to Detroit.

The settlers sought the oak openings, where the land was well drained, the timber thin, and the trees more easily removed. Soil was light in the upland areas and was readily worked. Continued exploitation of these soils is in part the basis for many present-day farm-management problems. The extensive poorly drained areas were at first avoided because of the difficulty of clearing and draining,

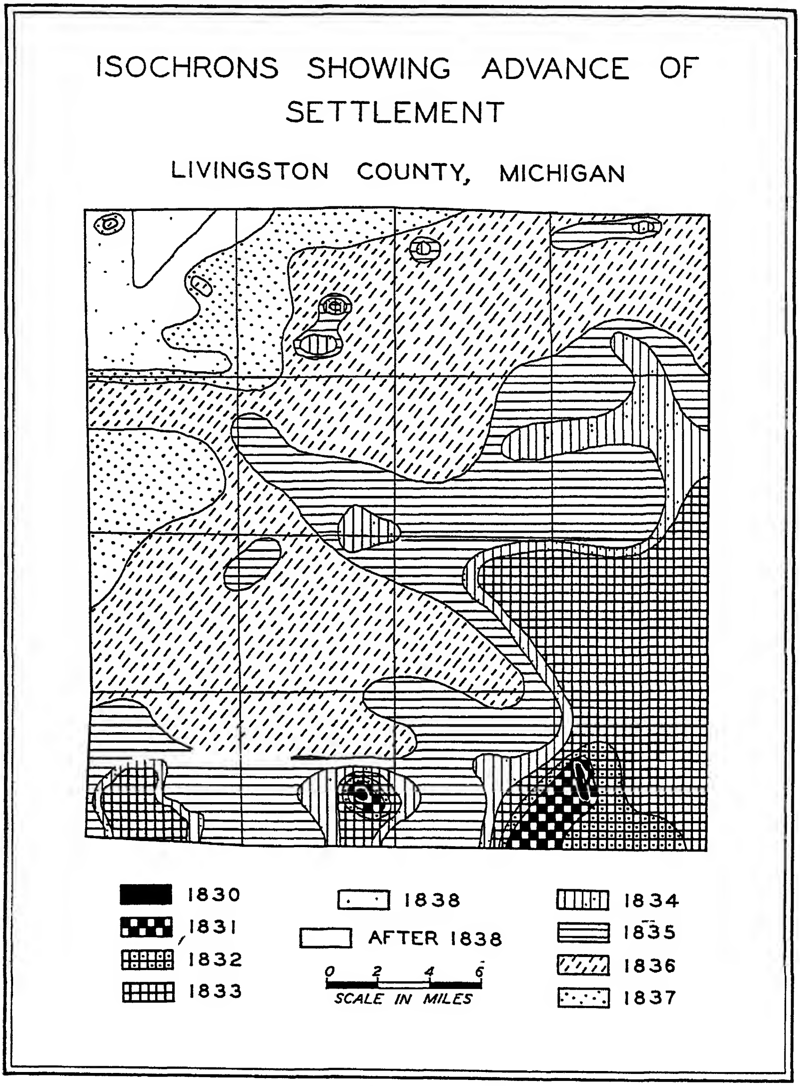


FIG. 5

and also because of the prevalence of malaria, or "the ague," as it was commonly called. The swamps and stream borders were used for pastures during the period of settlement.

Today as one drives through the county the construction of many of the old houses and the names of places give evidence of the New York State heritage of the people. The names of this county and the one adjoining it on the north repeat those of neighboring counties in New York. There, too, a river that flows through a part of Livingston County is called Genesee. The county seat of the Michigan Livingston County was named Howell in honor of Thomas Howell, a New York friend of the city's founder, Mr. Crane. More than names have been duplicated, however: houses are built after the

FIG. 6. Farmhouse in Marion Township, Section 35, on Shafer Road; now rented by an automobile worker

fashion of those in western New York (Fig. 6). This type of house, which resembles a T lying on its side, is very common in the rural districts of Livingston County, Michigan, and of neighboring counties. The windows usually have a number of small panes, and the cornices are ornately scrolled. There are roofs over the two front doors. When additional rooms were needed a wing was built, but the old part of the house is usually distinguishable (Fig. 7). Small bedroom windows above the porch on the left wing are very common. The house pictured in Figure 8 is well over a hundred years old; it shows the little windows under the front eaves plainly. There remain in the county a few examples of an old New England type of barn (Fig. 9), with all the buildings strung together. Because of the

FIG. 7. Farmstead in Unadilla Township, Section 13, on State Highway 36. The house was built in 1865; the right wing was added about 1910

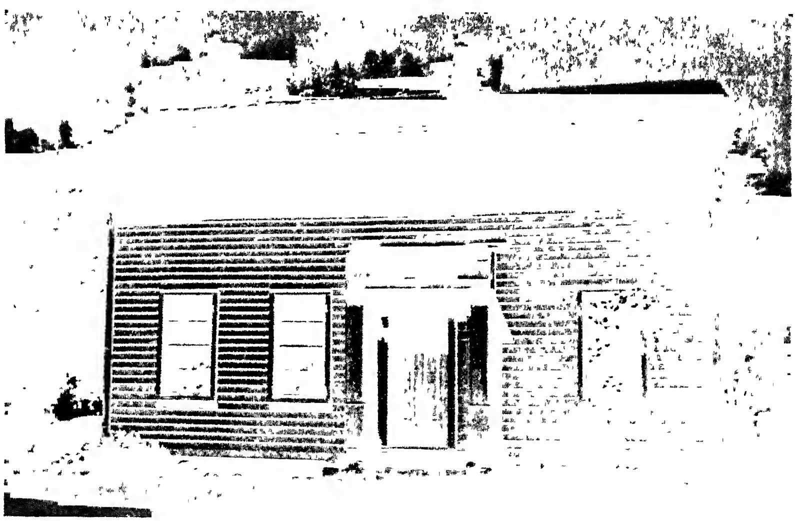


FIG. 8. Farmhouse in Putnam Township, Section 7, on Pingree Road

fire hazard and the farmers' desire to "modernize," barns of this sort are rapidly disappearing.

Although the prevailing type of rural house, as described above, was built in accordance with ideas brought from western New York by the early settlers, there is another important type which may be seen here and there in the rural parts of the county. The log cabin (Fig. 10), which had sheltered the pioneers in the first few years of

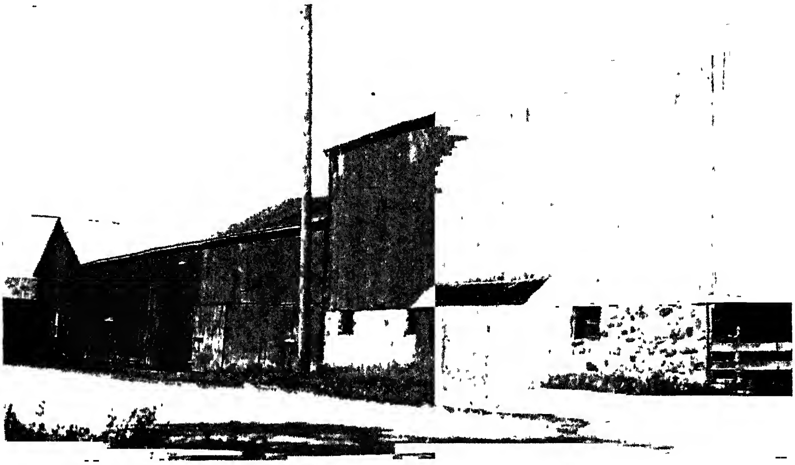


FIG. 9. New England type of barn, Putnam Township, Section 26, on Pinckney Road

settlement in the wilderness, was replaced by a more commodious structure, eclectic in style and elegant in taste.

The house of eclectic design was either of brick or of wood (Figs. 11–12), whereas the New York type was mostly built of wood. The increase in prosperity during the first few decades after settlement seemed to justify an elaboration of the house, and the eclectic type filled the esthetic and practical needs of the people of the period. There was an increase not only in prosperity, but in population. Part of it came from new immigration, part from additions to families already settled. Whenever it has been necessary to enlarge the original house, the New York type has lent itself readily to addition. As already noted, wings could be added (see Fig. 7) or built up with higher stories (Figs. 13–14).

It may be shown that most of the settlers came from western

FIG. 10. Log cabin in Genoa Township, Section 21, on Latson Road; built about 1830 by an Indian scout who was not a permanent settler

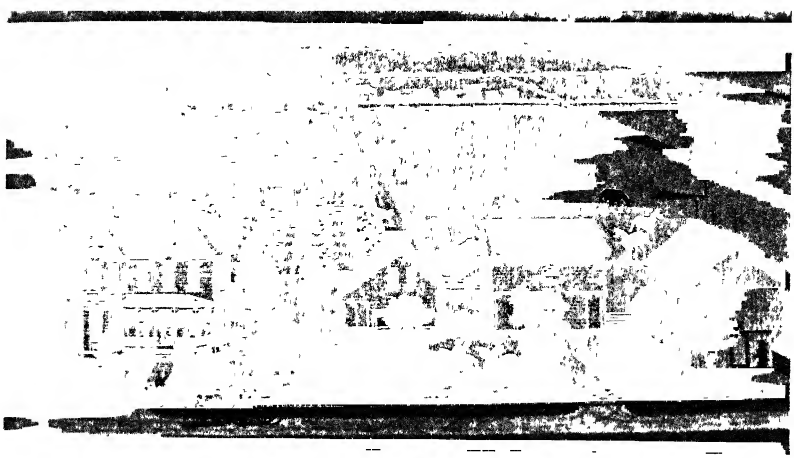


FIG. 11. Sketch of Daniel Gannon's farmstead in 1880; Cohoctah Township, Section 8 (from the *History of Livingston County, Michigan*)

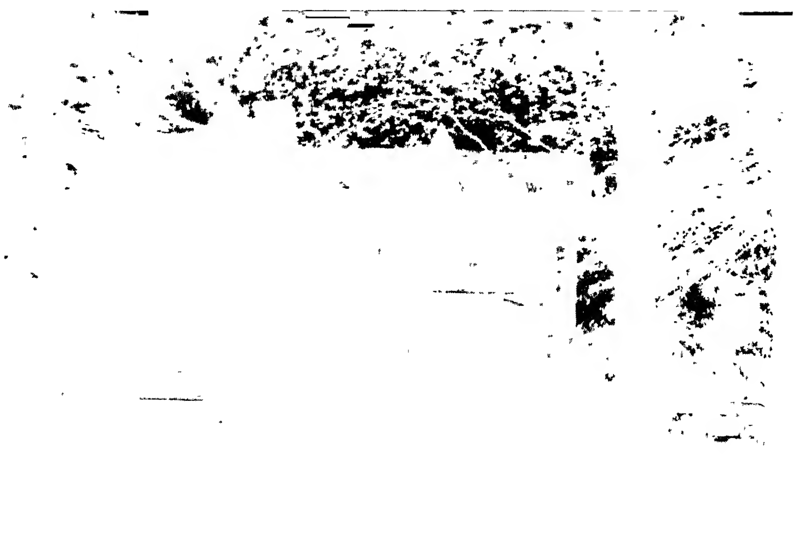


FIG. 12. The old Gannon residence as it now appears

FIG. 13. Artist's sketch of Mrs. Mary J. Jones's residence as it appeared about 1880; Cohoctah Township, Section 25 (from the *History of Livingston County, Michigan*)

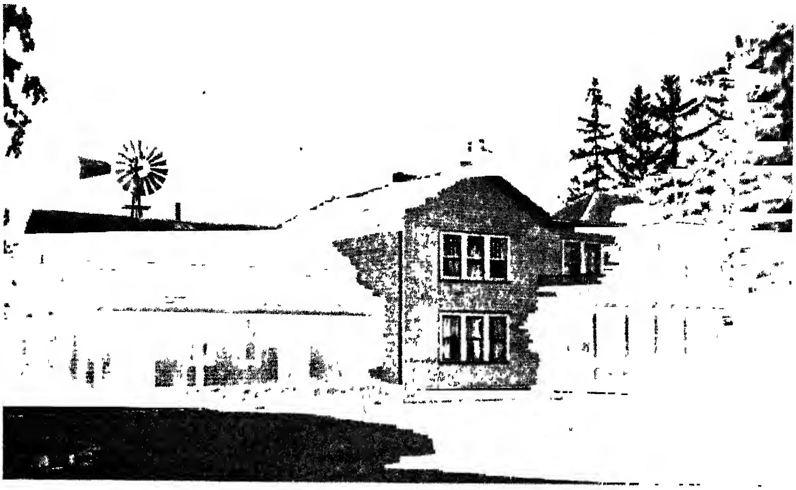


Fig. 14. The Jones house as it is today

New York, and detailed investigation merely confirms conclusions which may be drawn from a consideration of the essential features of the characteristic house. It duplicates those found in western New York. Subsequent changes in houses and in other buildings correspond to changes in economic conditions, which have affected all the area in the vicinity of Detroit.

Part II. Land Types and Land Use

INTRODUCTION

In the past several years much attention has been directed to the use and the abuse of rural land. Various techniques for land classification and crop mapping have been developed. The halting and prevention of soil erosion have been carried on in many areas. Advice on crop management has been freely given to the farmer, and much has been done to assist him in improving the condition of his land.

The following material is an attempt to connect some of the existing conditions and qualities of the land with happenings within the history of land use. In Livingston County such records are a matter of comparatively recent years. Permanent settlement began little more than a century ago, and large-scale agricultural practices

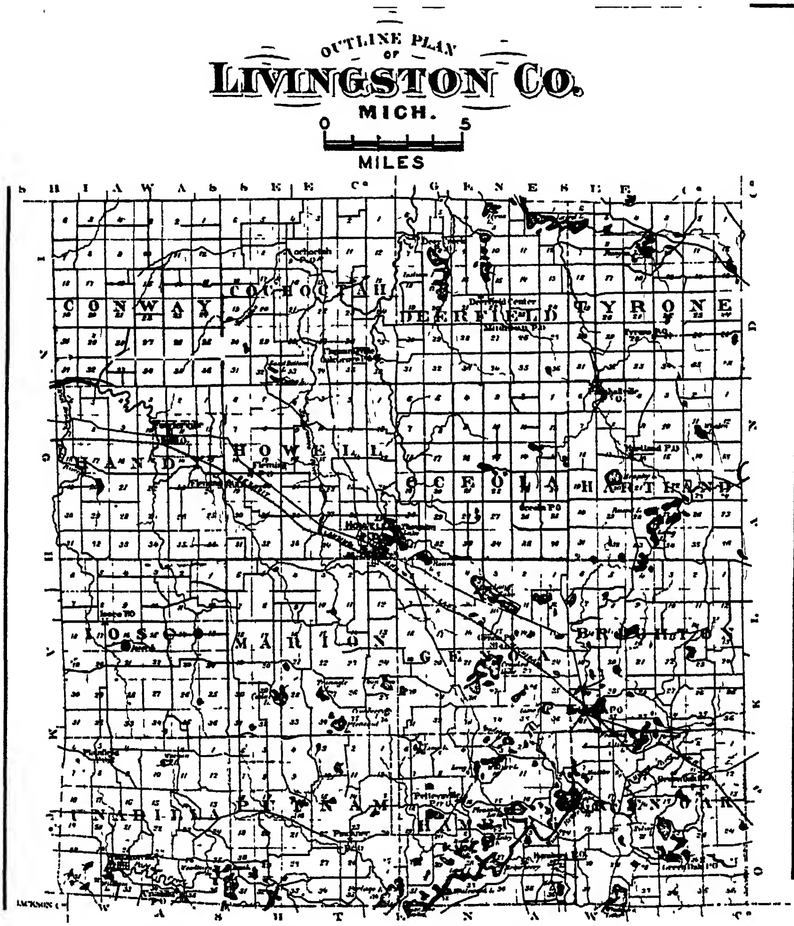


FIG. 15

are of even later date. On the farms which have remained under the control of a single family the history of land use comes within the span of three generations.

In a publication that appeared in 1940[2] a classification of land

[2] Dick, W. B., and Ware, S. J., "A Land-Type Map of Livingston County, Michigan," *Pap. Mich. Acad. Sci., Arts, and Letters,* 25 (1939) : 373–384. 1940.

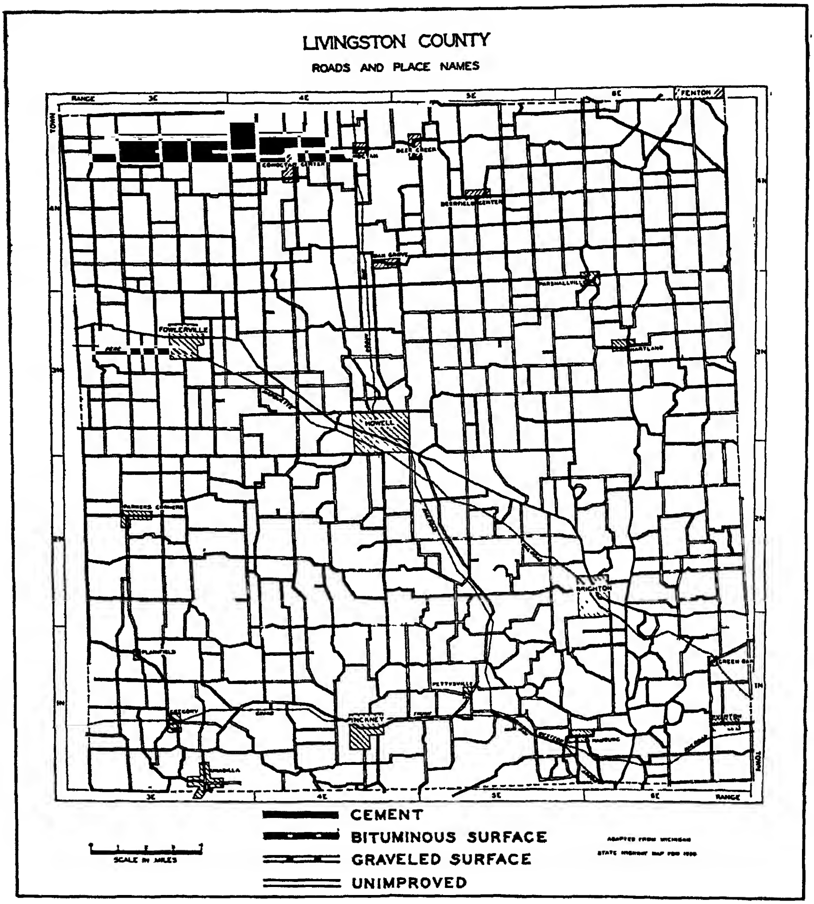


FIG. 16

qualities in Livingston County was developed. The present study shows some relations between these qualities and several phenomena of the method of occupance today. In the first part will be discussed a series of representative farms on which erosion and land-use history surveys have been made. These surveys note how past and present use of the land has caused soil erosion. The following sections will treat of the relations of land types to taxation and to financial conditions indicated by direct relief and farm mortgages.

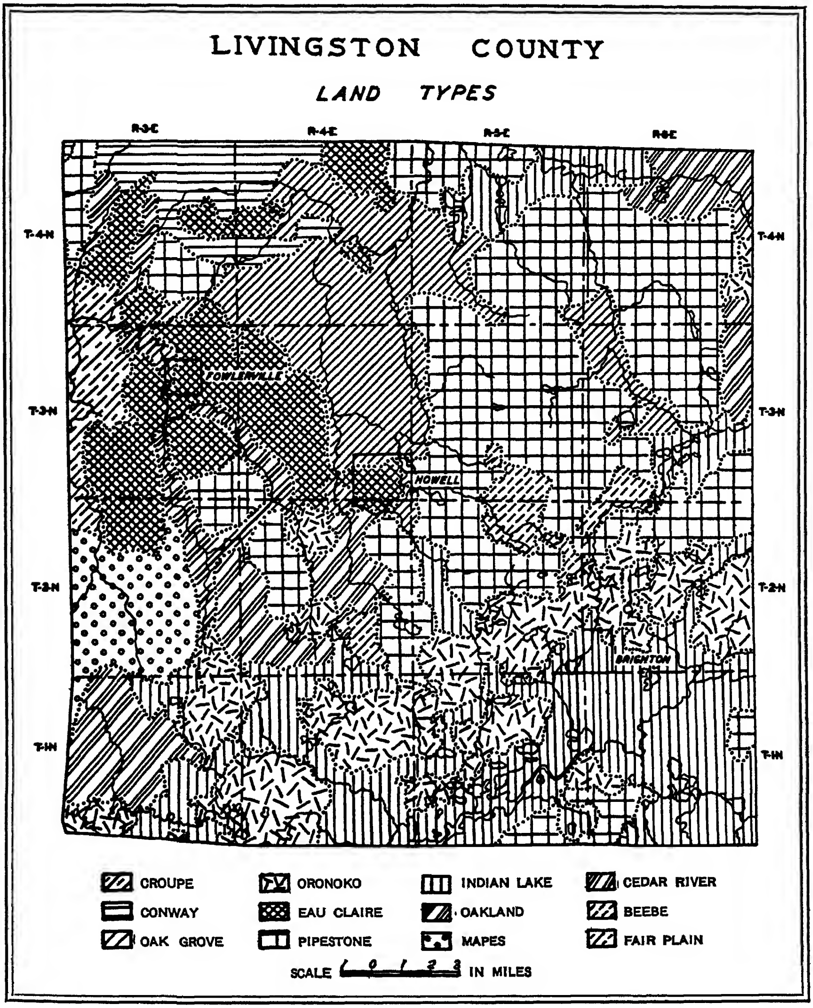


FIG. 17

Figure 15, an 1875 outline plan of Livingston County, gives the names and the arrangement of the sixteen townships comprising it. The road-classification map (Fig. 16) is based on recent information and is useful in the orientation of places mentioned in the text. The

land-type map (Fig. 17) is the result of field study carried on during the summer of 1939.[3]

SUMMARY OF LAND TYPES

Croupe. — Surface gently rolling, but broken by old river valleys, now cut to a considerable extent by artificial drainage ditches. Some swamp, but very little standing water. No lakes. Only a small amount of wild land. Soils very heterogeneous, mainly of the lighter types. Patches of Hillsdale loam, Plainfield sand, and Fox loamy sand with associated stream-bottom soils.

Conway. — Surface smooth to gently rolling, with large areas of very flat, artificially drained land, which at one time had been wet. Idle and pasture land predominant. Dominant soils Fox series and mucks, some of which have been drained and cleared for agriculture.

Oak Grove. — Rolling to hilly surface. Intermediate in relief. Considerable land in pasture. Soils dominantly Coloma loamy sand with Carlisle muck bordering the streams. Minor soils Miami loam and Plainfield sand. Sandier exposed hills subject to blowing in dry weather.

Oronoko. — Hilly, knob-and-basin terrain. Slopes two to three times the area of level upland; most slopes, 15 to 25 per cent or more; lake basins, dry depressions, and swamp basins. Dominant soils sandy loams mainly Bellefontaine and Hillsdale types, with smaller bodies of Coloma loamy sand, Fox loamy sand and sandy loam, and Miami loam.

Eau Claire. — Gently rolling till or clay plains. Surface similar to Croupe type. Short slopes, few exceeding 7 to 15 per cent; swales and shallow basins. Dominantly Miami and Hillsdale loam soils. May be moderately stony.

Pipestone. — Deeply rolling or broken, pitted or dissected clay land, till plains, or moraines. Slopes greater in area than level land; constructional swales and basins; generally considerable stream dissection. Dominant soils Hillsdale and Miami loams. Some muck and peat.

Indian Lake. — Sand-gravel plains; level surface but containing a large number of dry potholes, lake basins, muck and peat basins, swampy stream valleys, or chains of lakes. Slopes, enclosing basins for the most part, are short, but may have a grade of 25 per cent or more. Dominant soils Fox sandy loam and loamy sand, and Bellefontaine sandy loam. Some Plainfield sand and organic soils.

Oakland. — Intermediate in gradient and height of relief between Eau Claire and Pipestone on the one hand and Oronoko on the other; more Hillsdale and Miami loam soils than are found in Oronoko type. Slopes exceed area of level land; high percentage of slopes of 7 to 25 per cent gradient. Lakes and muck basins common. May be stony.

[3] For further information on the method of classification see J. O. Veatch, *Agricultural Land Classification and Land-Types of Michigan*, Agric. Exper. Sta., Michigan State College, Spec. Bull. No. 231, April, 1933; and "Classification of Land on a Geographic Basis," *Pap. Mich. Acad. Sci., Arts, and Letters*, 19 (1933): 359–365. 1934. Seven of the twelve land types had previously been mapped in adjacent Oakland County by J. O. Veatch and N. L. Partridge. The numbers and names used by them are followed in the Livingston County mapping.

Mapes. — Level and swampy with interspersed higher areas having slopes generally less than 7 per cent. Dominant soils Carlisle muck and Hillsdale sandy loam. May include some Fox soils. Wild land predominant with patch cultivation on the highlands. Lower relief and fewer lakes than in the Indian Lake type.

Cedar River. — Level, broad valley bottoms. Slow stream drainage, with some artificial drains. Similar to the Mapes type, but with little or no associated Hillsdale soil. Generally sinuous in outline. Soils mainly Carlisle muck. There may be small patches of Rifle peat. Surrounding upland chiefly Miami loam.

Beebe. — Swamp land, mainly Carlisle muck and Rifle peat, with small amounts of poorly drained mineral soils.

Fair Plain. — Smooth sand-gravel plains, slightly pitted or undulating. Few lakes and muck basins. Dominant soils Fox sandy loam and loamy sand.

SUGGESTED EVALUATION OF LAND TYPES FOR FARMING

Eau Claire, Pipestone, and, possibly, Oakland land types contain the major portion of soils which are most productive agriculturally. They are well drained for the greater part and lend themselves in varying degrees to general crop production.

Oronoko, Oak Grove, Fair Plain, and Croupe also are well drained. Within this group are slopes grading from steep in the Oronoko to gentle in the Croupe. Their agricultural possibilities are fewer, primarily because of the predominance of lighter and less fertile soils.

Conway, Mapes, Cedar River, and Beebe include the majority of the poorly drained areas. Their soils are for the most part of an organic nature and must be drained before crops can be grown. This group offers few possibilities for profitable farming.

Indian Lake is a mixture of steep slopes and level land, with both well and poorly drained areas. In general, it does not lend itself well to farming.

RELATIONSHIPS BETWEEN LAND TYPES AND LAND USE

In order that detailed information about land-use practices might be obtained a representative farm was chosen in each of the types (Fig. 18). In almost every case the farm has been under the ownership of the same family from the time of its first permanent settlement. The farms were carefully selected with the assistance of the township supervisors. A map was made for each one, showing cover, slope classification according to percentage groups, direc-

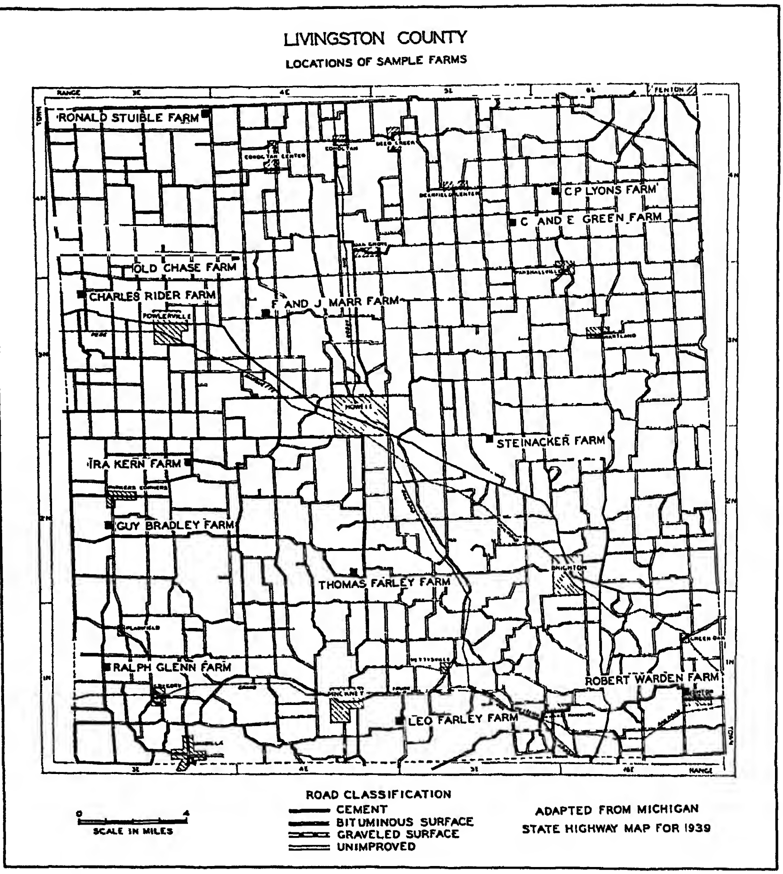


Fig. 18

tion of slope, and present depth of the A horizon in the soils. A master legend appears on page 366. The amount of erosion for each soil was calculated on the basis of the last item. These figures, plotted on an erosion map for each farm, were obtained by subtracting the present depths of the A horizons from estimated averages of depths that existed in the virgin soils.[4] The accuracy of the

[4] The averages were obtained through reference to the original Soils Survey of Livingston County and through consultation with Professor J. O. Veatch, of Michigan State College.

INFORMATION ON REPRESENTATIVE FARMS

LAND TYPE............

Name .... Township .... Section ....

Total acreage ....

I. Original settlement on farm
  A. Date ....
  B. By whom ....
  C. Nationality ....
    1. Place of origin of family ....
    2. How did they come? ....
  D. Original homestead
    1. Type of structure ....
    2. Material from ....
  E. Remarks ....

II. Sequence of land use
  A. Clearing of land
    1. Original cover ....
    2. Method of clearing ....
    3. Lumbering operations ....
  B. Early agricultural practices
    1. Type of crops ....
    2. Fertilization ....
    3. Rotation ....
    4. Yields ....
    5. Livestock ....
    6. Market and trading center ....
  C. Later agricultural practices
    1. Changes from earlier practices ....
  D. Present-day agricultural practices
    1. Type of crops ....
    2. Fertilization ....
    3. Rotation ....
    4. Yields ....
    5. Livestock ....
    6. Market and trading center ....

III. Erosion
  A. When first noticed and type? ....
  B. Anything done about it? ....
  C. When did yields decline? ....
    1. What was done about it? ....

IV. Drainage
  A. Artificial drainage ....
  B. Standing water ....
  C. Depth of well ....
    1. Any increase in depth? .... When? ....

V. Recreational use
  A. Lake subdivisions ....
  B. Hunting preserve ....
  C. Miscellaneous ....

VI. General remarks ....

MASTER LEGEND FOR SAMPLE FARMS

COVER

- B BEANS
- O OATS
- W WHEAT
- R RYE
- Bw BUCKWHEAT
- Al ALFALFA
- H HAY
- Cl CLOVER
- P PASTURE
- Wo WOODS
- C CORN
- X IDLE
- MARSH
- BUSH OR VINE
- Po POTATOES
- Gr GARDEN
- Or ORCHARD
- Ct CATHOLE
- PP PERMANENT PASTURE

SOIL

WELL DRAINED

- Hl HILLSDALE LOAM
- Ml MIAMI LOAM
- Fl FOX SANDY LOAM
- Fs FOX LOAMY SAND
- Co COLOMA LOAMY SAND
- Bs BELLEFONTAINE SANDY LOAM
- Ps PLAINFIELD SAND

POORLY DRAINED

- Cm CARLISLE MUCK
- Cm CARLISLE MUCK-SHALLOW PHASE
- Km KERSTON MUCK
- Rp RIFLE PEAT
- Bo BROOKSTON LOAM
- Bc BROOKSTON CLAY LOAM
- Gp GREENWOOD PEAT
- Hl HILLSDALE LOAM-POORLY DRAINED

SLOPE

- A 0-2%
- B 3-7%
- BB 8-15%
- C 16-25%
- D 26+%
- → DIRECTION OF SLOPE
- \+ SOIL DEPOSITION

GENERAL

- PROPERTY BOUNDARY
- FENCE
- COVER BOUNDARY
- ABANDONED HOUSE
- OCCUPIED HOUSE
- BARN
- IMPROVED ROAD
- UNIMPROVED ROAD

DRAINAGE

- INTERMITTENT
- STREAM
- Sp SEEPAGE

EROSION

SHEET-SHOWN IN INCHES OF A HORIZON REMAINING

GULLY-

estimates is problematic, but they are the best available. A schedule or interview sheet (see p. 365) was developed so that the data obtained would be uniform. Items were not taken up in any predetermined order, although all the necessary points were touched upon during conversations with each farmer, which sometimes lasted for several hours. Information obtained is presented on pages 367–390.

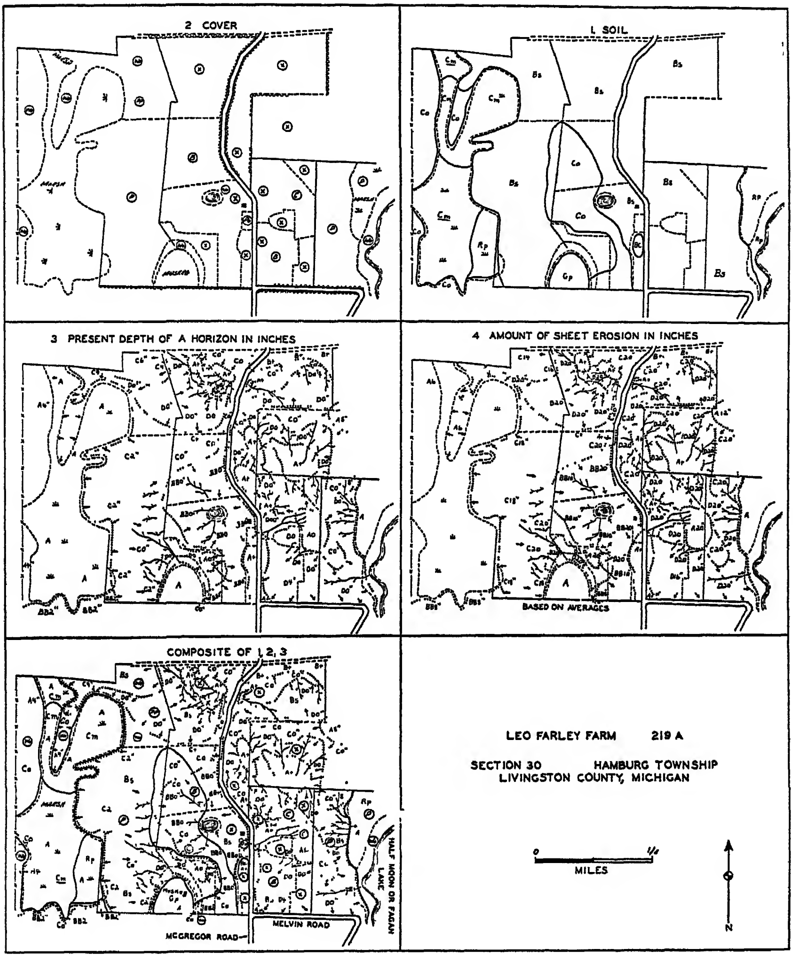


FIG. 19

INTERVIEWS WITH FARMERS

Oronoko Land Type. Leo Farley Farm, Hamburg Township, Section 30. 219 acres (Fig. 19)

This farm was settled during the time of the first permanent occupance in Hamburg Township (about 1830). The grandfather of the man now working the land emigrated from Ireland to New York

State. There he worked in a lumber mill at "the Little Falls" long enough to obtain money for his venture into farming in Michigan. He brought his wife and two children to Detroit by way of Canada, working as he could obtain employment along the way. Leaving his family in Detroit, he walked to this area by the Dexter route and investigated the land. He then returned to Detroit and purchased the patent from the Government Land Office. A log cabin was quickly constructed of local timber, and later a frame house, still in use, was built of lumber hauled from Brighton.

The original timber consisted mainly of oak and hickory and was removed by the process of cutting and burning. Almost as soon as the land was cleared wheat was planted. Little fertilization was needed at first, but after a few years animal manures came into use. The usual crop rotation for an individual field included, in the order named, corn, oats, summer fallow, wheat, and clover. Rotation was not rigidly followed. Yields of 30 to 40 bushels per acre were common. Many cattle and horses were kept, and the dairy products were sold along with other produce at Dexter and Hudson Mills, a gristmill on the Huron River not far from Dexter. Between 1870 and 1880 beef cattle and sheep began to assume considerable importance in the farm economy, and more hay was grown. Beans were planted each year, and the use of so-called "land plaster," a lime fertilizer, became common. This material was brought to Dexter in rock form on the Michigan Central Railroad. Farmers were paid one dollar a ton for hauling the rock to the mill at Dover, farther up the Huron River. There it was crushed and sold for four dollars a ton. Great powers were attributed to this fertilizer, and the land was heavily cropped with wheat and beans in the belief that no harm would result so long as land plaster was freely used. Migrant laborers came to Dexter by the railroad at harvest time. Most of these men were Swedish or English and were paid 50 to 75 cents a day.

Between the years 1880 and 1890 the farm was rented, and the tenants planted beans and wheat in as great quantities as was possible in order to make a quick profit. Yields declined, and erosion, which had been noticed as early as 1870, began to be a real problem. The soil, which had never contained much organic matter, soon became seriously eroded on the steep slopes and continues so to the present day (Fig. 20). The agricultural practices of today are

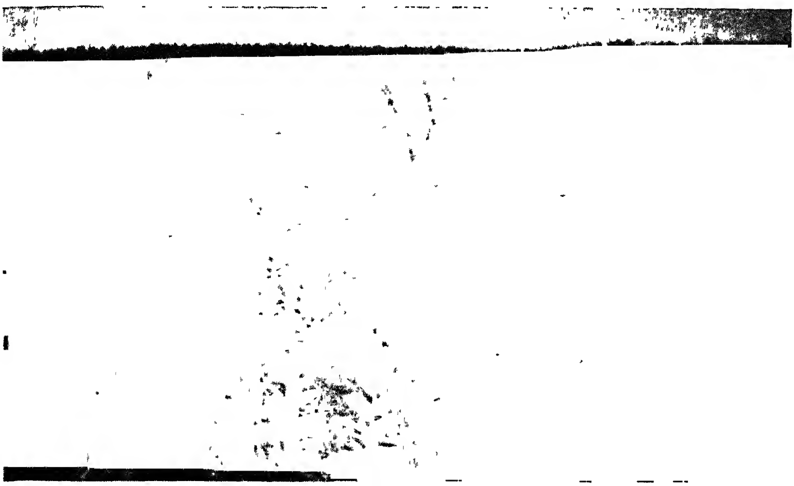


FIG. 20. Gully erosion in an idle field; Leo Farley farm, Putnam Township, Section 30

much curtailed in comparison with those of the past. Corn and beans are raised on the few remaining productive fields. No rotation or fertilization is practiced, and the yields are low. Money is obtained mainly by the sale of colts from a few breeding mares and the wool and meat produced from a flock of about 150 sheep. The present trading center is Pinckney.

Some ditch drains have been put in at the north end of the farm in a marshy plot of considerable extent. The well was originally hand-dug to a depth of 30 feet in sand and gravel, but in recent years has been drilled 30 feet deeper. This would seem to indicate a lowering of the water table. At its southern end the property borders Half Moon Lake and adjoins a real-estate subdivision. The present owner, feeling that there is little profit in the continuance of agriculture, hopes to sell at least this part of the farm for recreational development.

Eau Claire Land Type. F. and J. Marr Farm, Howell Township, Section 8. 150 acres in original plot (Fig. 21)

The grandfather of the two brothers now operating this farm bought it from the Land Office in Detroit in 1837. This family is of Scotch-Irish descent and originally emigrated from Europe to

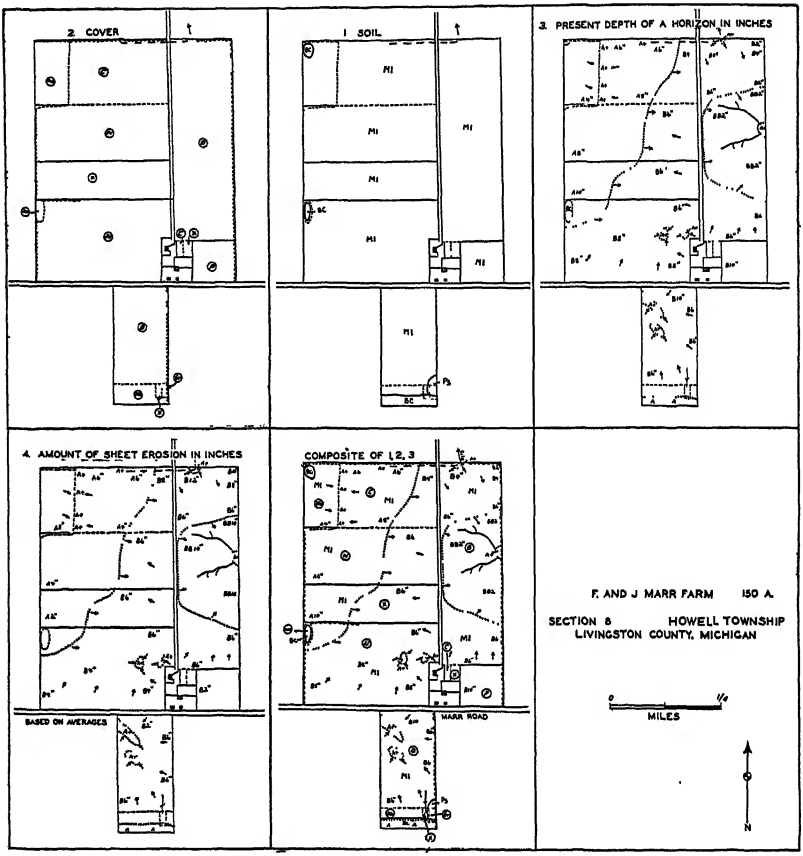


Fig. 21

Toronto, Canada. The man who first came to Livingston County was a member of a dissenting political minority in Canada. He was jailed by the government for his actions, but escaped and fled to the United States. The family was reunited in Buffalo and soon after set out for Detroit by boat. They built a log cabin from local timber, and in 1865 made a contract for a house to be built of brick from a brick-yard directly across the road. Owing to a labor shortage because of the Civil War the contract was not fulfilled. The brick-yard was closed at that time and never reopened. In 1870 the present frame house was constructed from lumber brought from

Owosso and Howell, and is now occupied by one of the Marr brothers; the other lives in a second frame dwelling built at a later date.

The original trees, which were mainly oak, hickory, maple, and ash, were killed by girdling, the customary method. They were then cut and burned. Since 1900 several portable sawmills have been brought in. Most of the present timber is third growth. Wheat was planted immediately after clearing, and corn soon followed. Animal manures were used as fertilizer, and little attention was given to crop rotation. Yields were good, the wheat being sold at Dexter and at Hudson Mills. Some trade was carried on at Howell. During the early 1870's beans and oats became an important part of the crop system. Because of the death of the father of the family in 1872 the land was heavily planted to cash crops, such as beans and wheat, in order that the heirs might be paid off by those who chose to stay on the farm. It was probably due to these practices that yields showed a marked decline about 1890. Land plaster was employed to some extent, but its use was soon discontinued because, in the opinion of the present owners, the results did not justify its cost.

An indefinite system of rotation is now customary. Generally two crops are grown, to be followed by a seeding to clover or alfalfa. The crops consist of corn, wheat, oats, and beans. Both hogs and cattle were raised until an epidemic swept through the stock a few years ago; since that time it has been impossible to maintain a healthy herd. Several horses and a flock of sheep are kept. The crops are fertilized by animal manures and some commercial fertilizer. With careful management the yields remain high. The principal markets are Howell and Fowlerville. Most of the heavy work is done with the aid of two tractors. Additional family income is gained through the operation of a combine for hire.

Erosion has never been a serious problem on this land, though a few small gullies have been apparent for a number of years. They are easily kept under control by filling with sandbags and brush, which are covered with earth. Tile drains are employed at several places on the farm. The well was originally dug 35 feet deep and encased in wood. Later it was drilled an additional depth of 40 feet, seemingly because of a lowering water table.

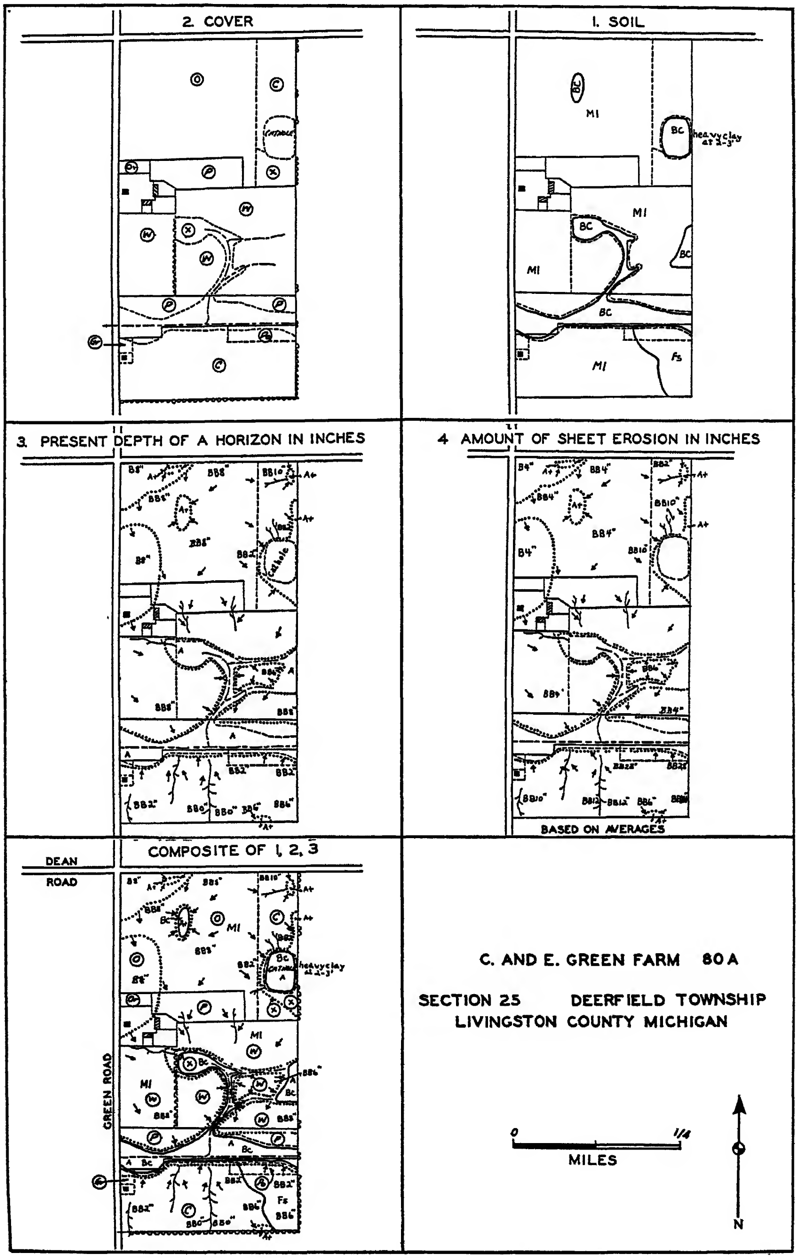
Pipestone Land Type. C. and E. Green Farm, Deerfield Township, Section 25. 80 acres in original plot (Fig. 22)

Two brothers now occupy the farm, which was purchased by their grandfather from the Detroit Land Office in 1837. The family came from England to New York City and thence to Michigan, although the route traversed from New York is not known. A log cabin was built from local materials near a creek now called Cranberry Creek. Farming provided the main source of Mr. Green's income, which was supplemented by the sale of rye whisky made in a still near the creek. When the Government imposed a tax on such liquors this production was discontinued. Later a frame dwelling was built on the site of the log cabin. In 1906 the frame house in which the two families now live was built on higher land some distance from the creek.

The original trees were mainly oak. They were cleared by the "cut-and-burn" method then common. Not all of the land was cleared, and as recently as the World War some virgin timber was available. Nearly 40 acres, about 350,000 board feet, were cut by a portable mill at that time. At least one half of this was white oak and was sold to the Government by the contractor for 80 dollars a thousand feet. The lumber was hauled to Oak Grove by wagon and shipped by the Ann Arbor Railroad. Most of the timber on the land at present is second-growth oak and hickory.

Early crops were chiefly wheat, rye, and corn. Animal manures were used to fertilize the soil, and rotation was not practiced. Oxen served as draft animals. Howesburg, near the present town of Cohoctah, was the leading trading center. About 1890 the owners began to grow beans in considerable quantities. Land plaster mixed with wood ashes was used as a fertilizer; according to Mr. Green, it killed cutworms in corn. Much seeding to clover was done, and the hay was fed primarily to the beef cattle, which by 1900 had assumed considerable importance in the farm economy.

The present-day crops are usually grown in the following rotation system: corn, oats, beans, wheat and clover or alfalfa seeding. Yields of 25 bushels of wheat and 100 bushels of corn to the acre are common. Commercial and animal fertilizers are used. A small herd of milch cows, two horses, sheep, and swine are kept. The heavy field labor is done with a tractor. Trading is carried on at Linden, Howell, and Fenton.



2. COVER
1. SOIL
heavy clay at 2-3'
3. PRESENT DEPTH OF A HORIZON IN INCHES
4 AMOUNT OF SHEET EROSION IN INCHES
BASED ON AVERAGES
COMPOSITE OF 1, 2, 3
DEAN ROAD
GREEN ROAD
C. AND E. GREEN FARM 80 A
SECTION 25 DEERFIELD TOWNSHIP
LIVINGSTON COUNTY MICHIGAN
MILES
N

FIG. 22

Erosion first became apparent about 1890, but it has never been serious, and the gullies which formed were easily kept from enlarging by plowing earth into them. Both ditch and tile drains are employed. The well at the site of the homestead was hand-dug to a depth of 18 feet; later on a point was driven some 25 feet deeper. The creek is dry throughout much of the summer, and the water table apparently is at a lower level than formerly.

Fair Plain Land Type. Thomas Farley Farm, Marion Township, Section 26. 160 acres (Fig. 23)

This farm is located in a land type of limited extent. Thomas Farley, the present owner, purchased the land in 1882, after it had been cleared and used for some years. The origin of the family is given in connection with the other Farley holding, in Hamburg Township, which is operated by Leo, Thomas' son (see p. 367).

Owing to the pitted land surface in this type agriculture is difficult. Sheep and beef cattle have been the main source of income in the past, with hay and corn grown to feed the animals. It should be noted that this was but the continuation of practices common to both Farley farms. At present, except for a small garden plot near the house, no agriculture is attempted.

Erosion is in evidence, but is scarcely active, being held in check by the native grasses and wild hay. No artificial drainage can be seen, and there are numerous catholes, many of which are dry toward the end of the summer. The original well was quite shallow, but when a new well was recently sunk it was necessary to go considerably deeper to obtain water.

Indian Lake Land Type. Robert Warden Farm, Green Oak Township, Section 23. 200 acres (Fig. 24)

The patent for this land was purchased from the Government in 1833 by a man interested in reselling it. Some few years afterward it was bought by the father of the present owner, who had emigrated from Scotland in 1832 and came to Michigan by horse and wagon by way of Canada, after having lived in New York State for a short while. The frame house, which was also the original homestead, was built in 1843 of local material.

The virgin timber consisted largely of oak trees, which were girdled and later cut and burned. Fires set by the Indians were

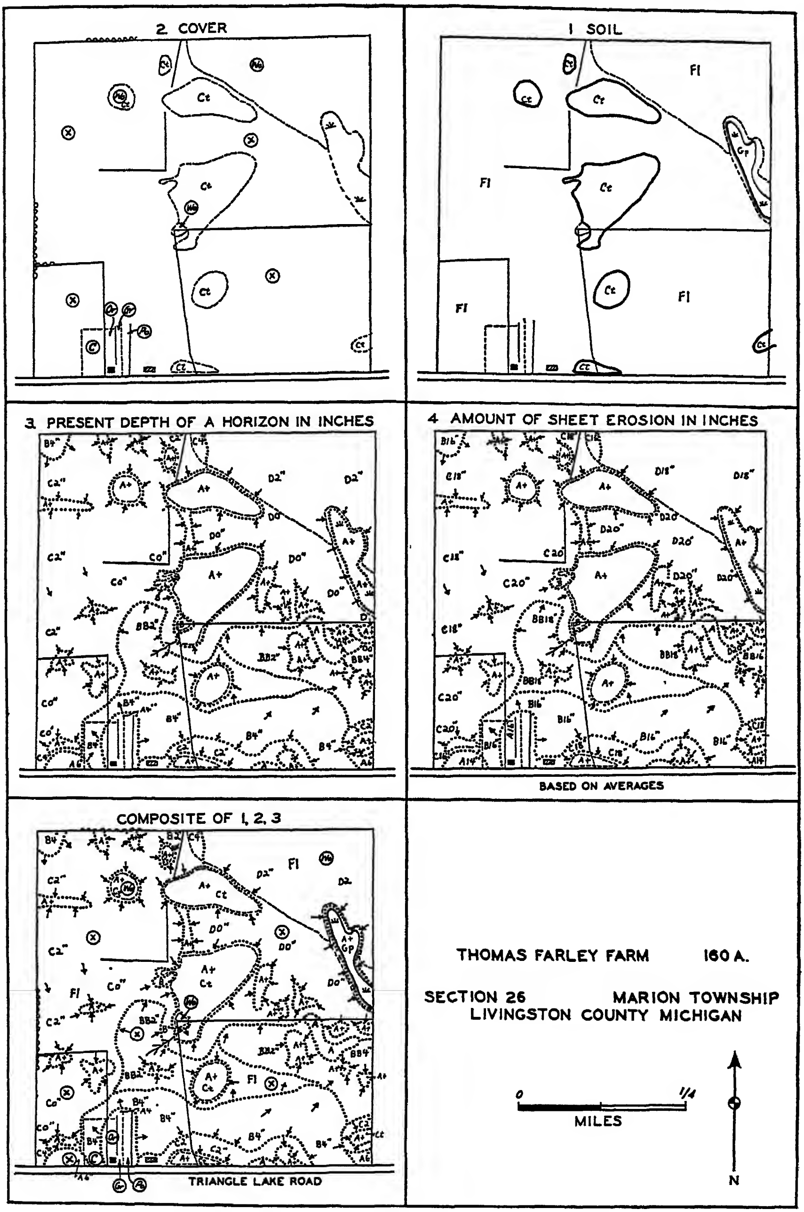

2. COVER
1 SOIL
3. PRESENT DEPTH OF A HORIZON IN INCHES
4 AMOUNT OF SHEET EROSION IN INCHES
BASED ON AVERAGES
COMPOSITE OF 1, 2, 3
TRIANGLE LAKE ROAD
THOMAS FARLEY FARM 160 A.
SECTION 26 MARION TOWNSHIP
LIVINGSTON COUNTY MICHIGAN
0 1/4
MILES
N

FIG. 23

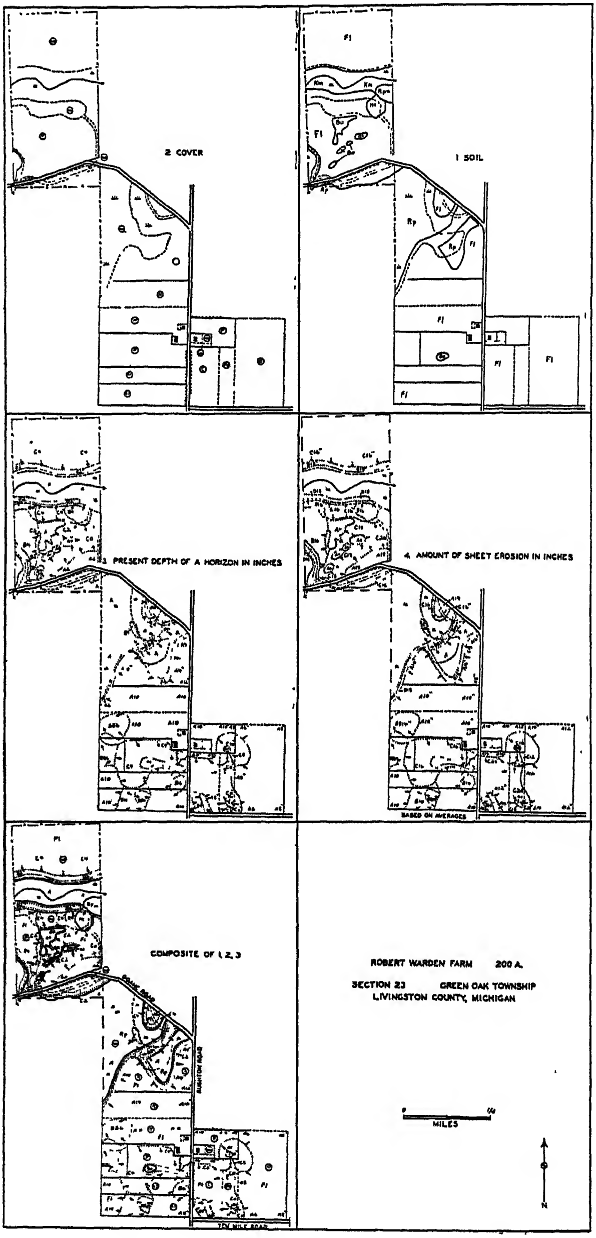

2 COVER
1 SOIL
3 PRESENT DEPTH OF A HORIZON IN INCHES
4 AMOUNT OF SHEET EROSION IN INCHES
BASED ON AVERAGES
COMPOSITE OF 1, 2, 3
ROBERT WARDEN FARM 200 A.
SECTION 23 GREEN OAK TOWNSHIP
LIVINGSTON COUNTY, MICHIGAN
MILES
TEN MILE ROAD
RUSHTON ROAD

FIG. 24

frequent then, and considerable timber and marsh grass were destroyed at various times during the early period. A sawmill was built at Rushton in 1833 and another in 1838. Marsh hay played an important part in the early economy because it was useful for feeding until the land was cleared and "tame" hays could be established. The first crops were wheat, buckwheat, corn, and oats. No regular system of rotation was used, and the only fertilizer was animal manure. Wheat generally yielded about 30 bushels to the acre. Only a small number of livestock were kept; oxen served as draft animals. Ann Arbor was the trading center. About 1880 beans were raised in large quantities for the first time, and the land was fertilized by a mixture of ground lime and gypsum. This material was similar to the land plaster employed on farms in other parts of the county. Yields were beginning to decline at that time, and wheat had dropped to between 20 and 30 bushels to the acre.

Previous to the summer of 1939 Mr. Warden's son, a graduate of Michigan State College, worked this farm. The rotation system was utilized, the crops being corn, oats, wheat, alfalfa, and some potatoes. The only fertilizer necessary to produce good yields was manure. A herd of milch cows was maintained, and a few horses were kept for draft purposes. Since the death of the son early in 1939 the land has been rented in accordance with the regulations of the Agricultural Adjustment Administration. South Lyons has been the trading center since the Pere Marquette Railroad was built through that town in 1871.

Some erosion is to be seen, particularly on the northern part of the farm, which is now used exclusively for pasture. Gullies were first noticed about 1885, but erosion has never been serious so far as agriculture is concerned. No artificial drainage is employed. The well, which is in gravel, is 29 feet deep and has never needed deepening.

Oakland Land Type. Ralph Glenn Farm, Unadilla Township, Section 17. 160 acres in original plot (Fig. 25)

This farm was taken up from the Government in 1840 by the present owner's maternal grandfather, who was an Englishman. The family came by boat to Detroit, and thence to Livingston County by horse and wagon after the land had been duly inspected by the prospective owner. It was judged to be good for agriculture because

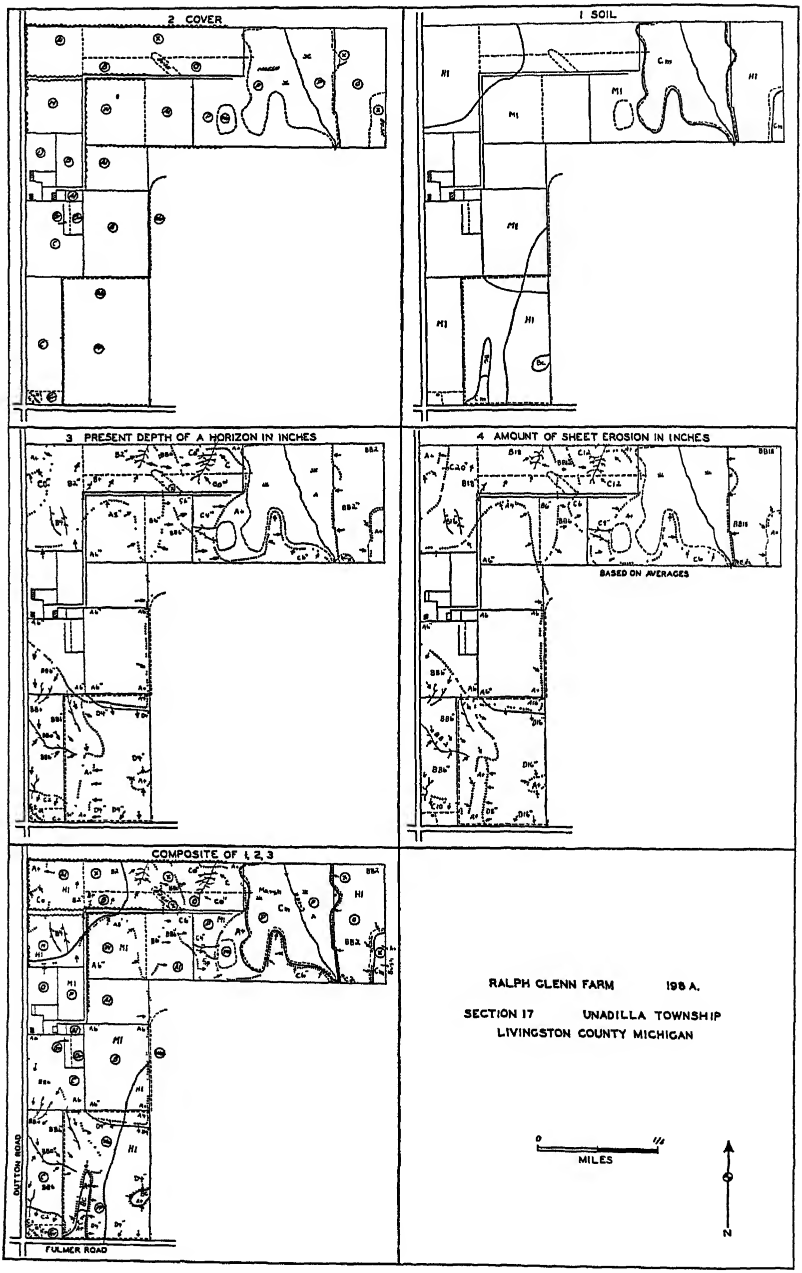

2 COVER
1 SOIL
3 PRESENT DEPTH OF A HORIZON IN INCHES
4 AMOUNT OF SHEET EROSION IN INCHES
BASED ON AVERAGES
COMPOSITE OF 1, 2, 3
RALPH GLENN FARM 198 A.
SECTION 17 UNADILLA TOWNSHIP
LIVINGSTON COUNTY MICHIGAN
MILES
N
DUTTON ROAD
FULMER ROAD

FIG. 25

of the prevalence of hazel brush, which supposedly was an indicator of good soil. The original home, built from local lumber, was a frame structure.

Oak and hickory were predominant in the original cover, which was cleared by the cut-and-burn method. A number of years ago considerable lumber was sawed at a mill in Plainfield. The last mill to do any sawing in this section was a portable one, which was moved out about 15 years ago. Wheat was the first crop to assume any commercial importance on this farm. Average yields were about 40 bushels an acre. Beans and timothy hay were also grown, in rotation with wheat. At first Dexter was the main trading center, but later Stockbridge rose to primary importance as a place of business for these people. As time passed clover and alfalfa were grown in place of timothy; beans were planted in large quantities in the late 1870's.

The cropping system of today rotates corn with oats and wheat. Beans instead of wheat are sometimes planted after oats. Much alfalfa and clover are grown; occasionally these crops are allowed to remain in the soil for the winter, after which they are plowed under. The wheat yields well, usually 30 to 35 bushels an acre. Commercial fertilizer is employed almost exclusively. A tractor supplies power for the plowing and other field preparation. A herd of dairy cattle is maintained, and sheep are kept chiefly for their wool. Stockbridge remains the trading center. The farm is managed in accordance with the program of the Agricultural Adjustment Administration.

Gully erosion was first noticed about 1880, but preventional methods were not taken until some time later. Plowing-in of gullies and retirement of gullied areas from cropping now prevent further erosion. Practically no artificial drains are used. The well at the house is 15 feet deep.

Beebe Land Type. Steinacker Farm, Genoa Township, Section 3. 80 acres (Fig. 26)

The present owner's father bought this farm from the man who took out the land patent. The family came to this section directly from Germany by way of New York City, Lake Erie, and Detroit. The first house was a log cabin, which was later replaced by a frame house built from lumber supplied locally. After it burned some years ago the present frame structure was erected.

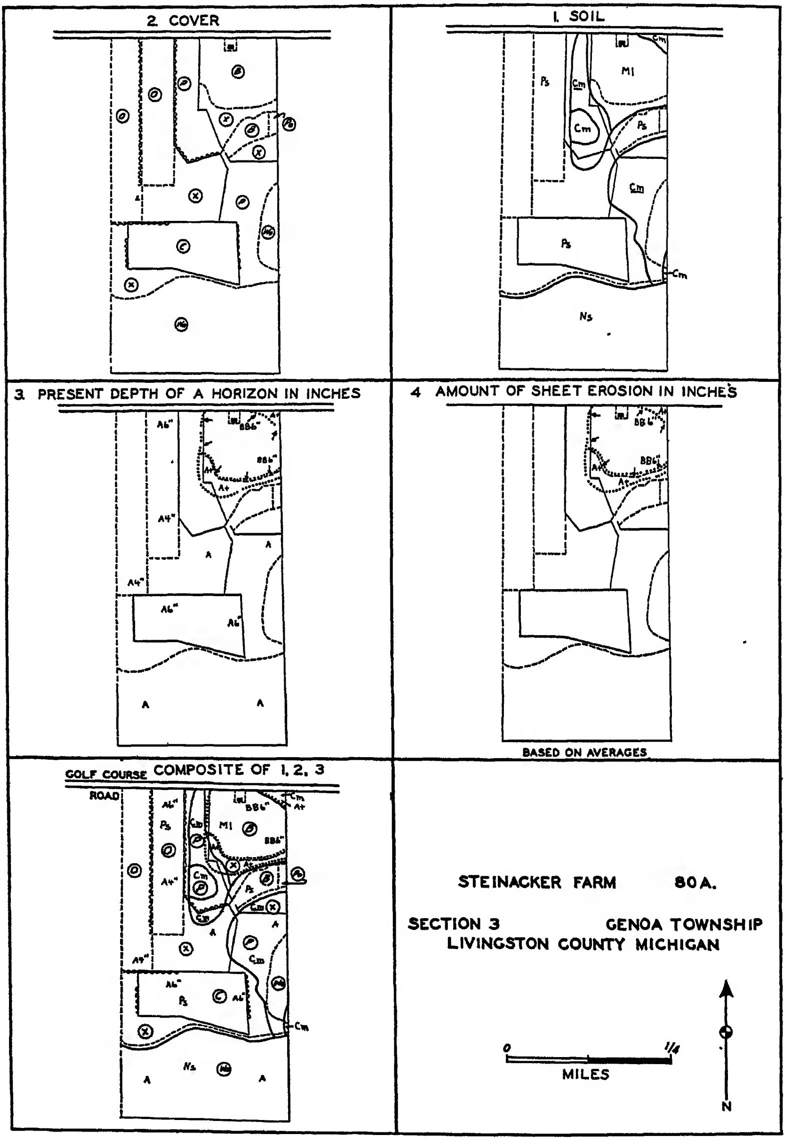

2. COVER
1. SOIL
3. PRESENT DEPTH OF A HORIZON IN INCHES
4. AMOUNT OF SHEET EROSION IN INCHES
BASED ON AVERAGES
GOLF COURSE
ROAD
COMPOSITE OF 1, 2, 3
STEINACKER FARM 80 A.
SECTION 3 GENOA TOWNSHIP
LIVINGSTON COUNTY MICHIGAN
0
1/4
MILES
N

FIG. 26

The original timber was chiefly of the swamp type, but some oak and hickory grew in the drier places. The clearing was accomplished by cutting and burning. A sawmill was built near by in the town of Howell, and portable mills were brought in at various times for the cutting of local timbered areas. Owing to the nature of the soil and surface only 30 of the 80 acres on this farm are useful for agriculture. Some member of the family has always worked elsewhere to supplement the income from the land. Early practices included the growing of rye, oats, and corn. Manure was used to fertilize the soil, and oats yielded about 50 bushels per acre, with corn averaging between 60 and 70 bushels. About 1870 land plaster served as a fertilizer along with manure. Beef cattle and sheep were grazed on the marsh hay. Family income was increased by selling eggs at Howell, the market place.

Of recent years farming has become even less important on this land. The owner is too old to be active, and his son obtains part-time employment elsewhere. Beans, corn, oats, and hay are grown in accordance with the stipulations of the farm program of the Agricultural Adjustment Administration. Small amounts of commercial fertilizer are used as they can be afforded. One horse, one cow, and a flock of chickens for the Howell market constitute the livestock. Drainage is greatly needed, since 50 of the 80 acres are poorly drained. There is no noticeable erosion. The well was first hand-dug to a depth of 15 feet and later deepened by driving a well-point an additional 17 feet.

Mapes Land Type. Guy Bradley Farm, Iosco Township, Section 20. 150 acres (Fig. 27)

The early ownership history of the farm is not known. The father of the present owner came to this section about 1850. He bought a 160-acre farm near by and continued to purchase land until at one time he owned 1,200 acres, of which the present 150-acre farm was a part.

The original cover on this land, largely oak, was cleared by the cut-and-burn method. Early crops were wheat, corn, and clover, which were fertilized by animal manures spread on the soil by hand. Fowlerville, the trade center in the early days of settlement, has remained so to the present day. Changes from early practices in agriculture included a great increase in bean growing in the 1880's.

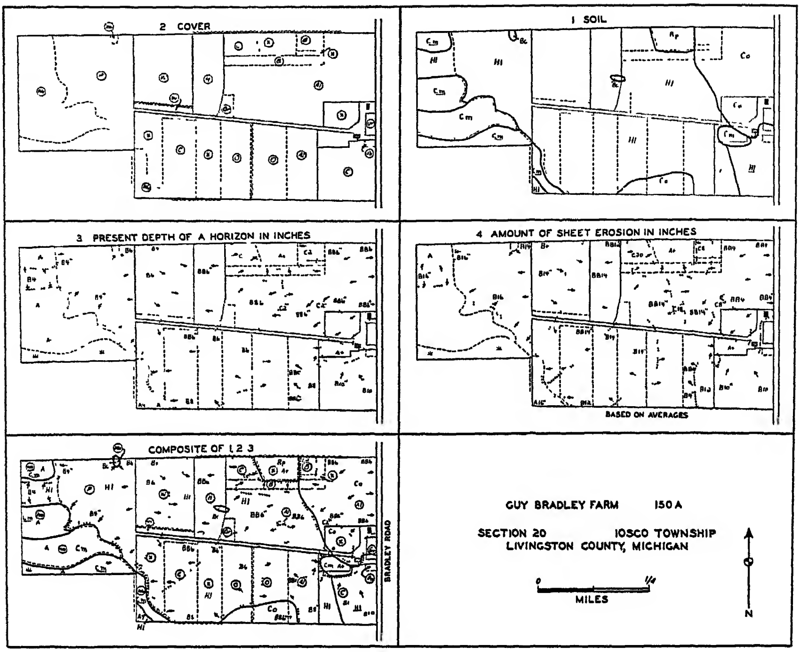


Fig. 27

Dairy cattle and sheep became increasingly important, and a cheese factory was established locally in the late 1880's, only to be changed to a bean-grading factory within a few years. Land plaster was the fertilizer during this period.

Today land use includes the rotation of corn, oats, summer fallow or beans, wheat, and alfalfa or clover in the order mentioned. Commercial and animal fertilizers are applied to the soil, but yields are not high. Twelve to 15 bushels of wheat to the acre are usual, and corn generally produces about 50 bushels to the acre. Mules and horses are used for draft purposes, while a herd of milch cows is maintained and some sheep and swine are raised.

Erosion never has been particularly noticeable on this land, but the few gullies that develop are plowed in with earth each spring. There has been only a small amount of artificial drainage. The house well has been drilled to a depth of 150 feet; a stock well near the barn about a hundred yards distant, is only 9 feet deep.

Cedar River Land Type. Ira Kern Farm, Iosco Township, Section 2. 50 acres in original plot (Fig. 28)

The family of the present owner of this farm did not originally settle or clear the land. The 171 acres shown on the map have been owned by the Kern family only since the late 1800's, but the land-use history of this area was familiar to the individual interviewed. The original living quarters were built from logs cut near by. Later a frame house was constructed.

Oaks, which comprised the original tree cover to a great extent, were cleared by cutting and burning. For a number of years a sawmill was located within a mile of the farm. In the days of early settlement wheat was the most important crop. Small amounts of manure were used as fertilizer, and rotation was given much attention. Wheat yields were about 40 bushels to the acre and corn about 100 bushels. Livestock was kept only in small numbers, mainly for the use of the family. Wheat was taken for grinding to Birkett's Mill on the Huron River near Dexter. Howell served as a trading center. About 1890 changes occurred in the farm economy with the planting of beans in larger amounts and the use of land plaster as a fertilizer. Sheep and beef cattle increased in numbers.

Tenants now occupy the farm, but the cropping system is carefully observed by the owner. Rotation is in the following order: corn oats, sometimes beans, and wheat. Seeding to alfalfa follows either the wheat or the oats. Yields of 25 to 30 bushels of wheat and 50 to 60 bushels of corn per acre are general. Dairy cows, beef cattle, and sheep are pastured on the abundant marsh grasses. The trade centers are Howell and Fowlerville. A few horses do the lighter labor, but a tractor is used for the heavier field work.

Not much erosion has ever been noticed. The Cedar River was dredged some thirty years ago, and the land is quite well drained, except for the lowland pasture. A small amount of tile drain has been laid. The well, which was originally hand-dug for 30 feet, has since been deepened 70 feet. Mr. Kern feels that the dredging lowered the water table and so caused the lowland muck areas to become dry. These lowland areas formerly provided a large amount of marsh hay and good pasture.

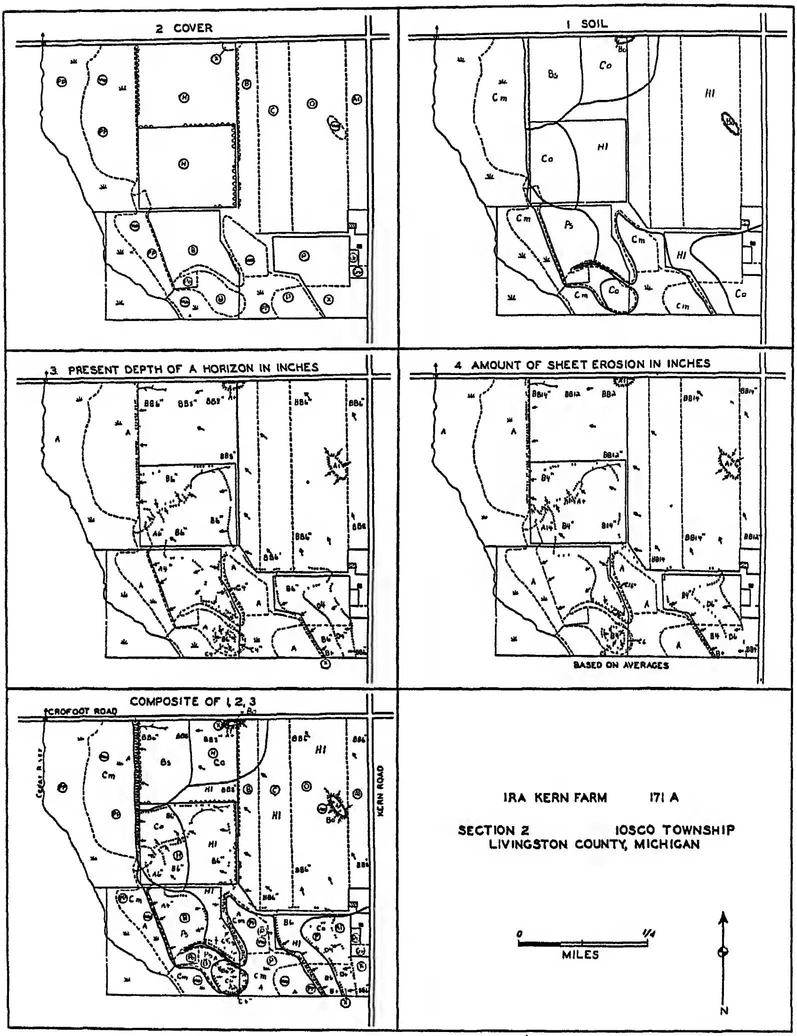


FIG. 28

Croupe Land Type. Charles Rider Farm, Handy Township, Section 6. 80 acres in original plot (Fig. 29)

The Rider family came to Detroit by boat from New York State in 1833, first settling in Oakland County. In 1835 they moved to

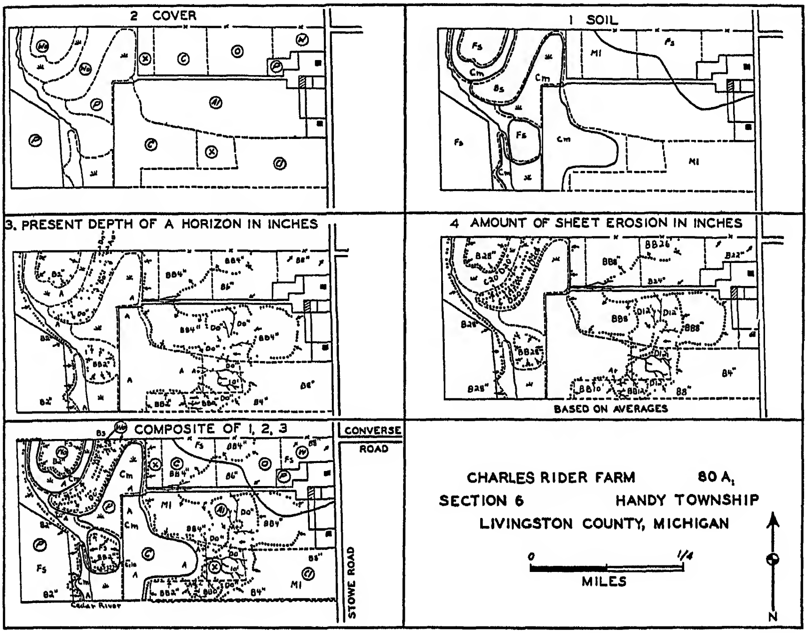


FIG. 29

Genoa Township in Livingston County, from which place the father of the present owner moved when he purchased this farm in 1870. The land patent was taken up in 1843 and passed through other hands before coming into possession of the Riders. During this time the land had remained uncleared except for two acres planted to wheat, but a few trees had been girdled. A log cabin built of local materials was replaced by a frame house in 1889. The lumber, white pine, came from Flint, where it cost 13 dollars a thousand board feet. Within the next year the price of similar lumber rose to 23 dollars a thousand feet. Mr. Rider and his son jointly manage the farm. The son occupies the old house; his father lives near by in a newer one.

The original forest was mainly of oak. Most of it was cut down and burned to start the clearing process, but later some of the better remaining timber was sold to the sawmill in Webberville for 10 dollars per thousand feet. As soon as the land had been cleared, corn, oats, wheat, and clover were planted in a rotation system in the order

mentioned. Land plaster and manure constituted the fertilizers, and the yields seem to have been somewhat higher than at present. Many of the farmers had great faith in the powers of land plaster, believing that "you could write your name on the field with 'plaster' and later see it in the crops." Horses and oxen were used for all draft work, and livestock was raised to sell in the Detroit market. In the early days the meat was hauled to Detroit in a wagon drawn by oxen. Wheat was taken for grinding and sale to Dover on the Huron River. Trade was primarily at Fowlerville.

Corn, oats, and wheat now follow one another in the planting system. Beans are sometimes grown before wheat and seeding to clover or alfalfa usually follows the wheat harvest. Manure and commercial fertilizer were used until 1936, when the latter was discontinued because of its expense. Yields of corn remain fairly constant at 80 to 100 bushels an acre. No dairying is practiced, but in the spring of 1939 forty steers were purchased in Iowa to be fattened for the market. The principal center of trade is still Fowlerville.

Gully erosion became apparent soon after the land was cleared. No preventive measures were taken at that time, but for a number of years corn stalks have been thrown into the worst gullies and covered with earth. Since the gullies have lately become larger it is planned to retire the worst areas from cropping and to seed them with hay. Power is obtained primarily through the use of two tractors. Some tile drains have been introduced where needed. Previous to the dredging of the Cedar River in 1916 there was considerable standing water throughout the early summer of each year, but since then surface water remains only during the early spring. The first well, which was hand-dug, was stoned to a depth of 35 feet, but it has lately been drilled an additional 75 feet.

Conway Land Type. Ronald Stuible Farm, Conway Township, Section 1. 211 acres (Fig. 30)

The major part of this farm was purchased from the Government Land Office in 1837. It came into the Stuible family about 1880 through its sale to the grandfather of the present operator. The family is of German origin, but no information is available concerning the route by which they came to Livingston County. The first dwelling was of the usual log type, of local timber. Not long after

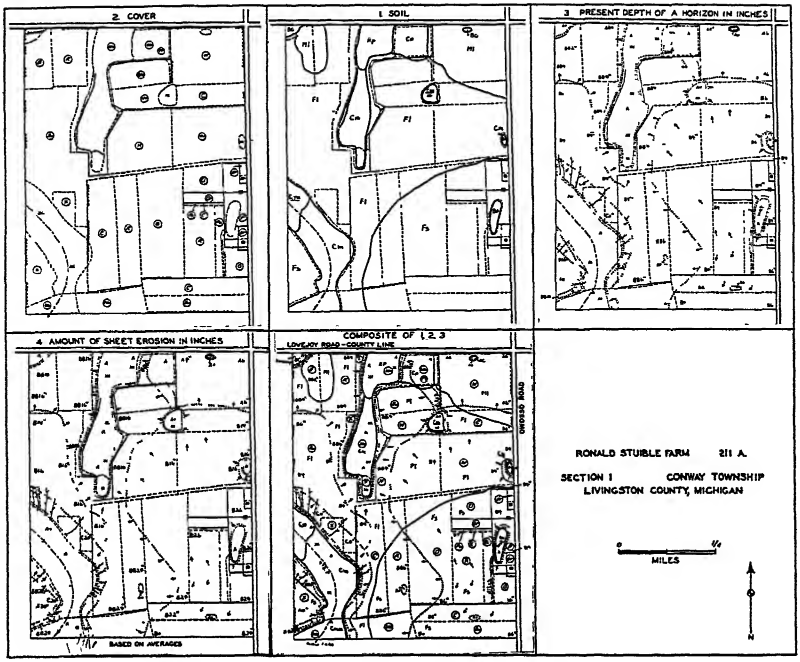


FIG. 30

the Stuibles settled on the farm they built the frame structure which is still in service, although it has been remodeled since that time.

In the days of early settlement the trees were mostly oak and hickory. Clearing was done by cutting and burning. A sawmill in Cohoctah (then also known as Sprungtown) provided a market for the better timber. Later portable mills were brought into the area at various times. Wheat, oats, corn, and timothy-clover hay were planted with no particular attention to rotation and without any fertilizer. Yields were somewhat higher than are those of today; 40 bushels of wheat and 60 to 70 bushels of oats per acre were common. Sheep and a few dairy cattle were raised. The town of Bancroft in Shiawassee County served as the principal trade center. Dairy cattle and beef stock became more numerous as transportation facilities developed. During the last decade of the nineteenth century land plaster was used along with manure for fertilizer.

Today crop rotation is carefully followed in the planting sys-

tem. The usual order is corn, oats, wheat, and alfalfa or clover, but sometimes beans are planted before wheat. Rye or buckwheat occasionally replaces the other grains. Of late years both animal and commercial fertilizers have been employed, with the yields remaining at about 25 and 35 bushels an acre for wheat and oats respectively. Only a few animals are maintained; the field work is done almost entirely by power machinery. The farm income is supplemented by the operation of a combine during the threshing season. Most of the trade is carried on at Howell or Fowlerville.

A few gullies have been noticed on the steeper slopes since about 1900. The worst ones have been checked successfully by filling them with straw and earth, and the immediate area has been retired from cropping. Both ditch and tile drains are used, but there is considerable standing water in the marshes during the spring and early summer. The well, which was drilled to a depth of 80 feet, has never been deepened.

Oak Grove Land Type. Old Chase Farm, Cohoctah Township, Section 31. 100 acres in original plot (Fig. 31)

This land was taken up from the Government in 1834 by the grandfather of the man who was working the farm in 1920 and who owned the farm adjoining. The family, which originated in England, lived in New York State for some years. It came to Michigan by the land route along the south shore of Lake Erie. In 1920 the farm was sold outside the family. Tenants have been operating it for the last twenty years. In 1834 a log cabin was built, but not many years had passed before a frame house was erected. That has since been replaced by another wooden building, in which the present tenant now lives.

White oak, red oak, hickory, and maple constituted the bulk of the virgin vegetation, which was cleared by the usual cut-and-burn method. In the days of first settlement there was little lumbering, but later the better white oak brought a good price and was sawed by portable mills. In the early period crops were mainly wheat and corn. Neither rotation nor fertilization was practiced. The wheat was drawn to Birkett's mill on the Huron River, and Howell was the chief trade center. Few animals were raised, but by the late years of the nineteenth century the breeding of both dairy and Hereford cattle had become an important part of the farm

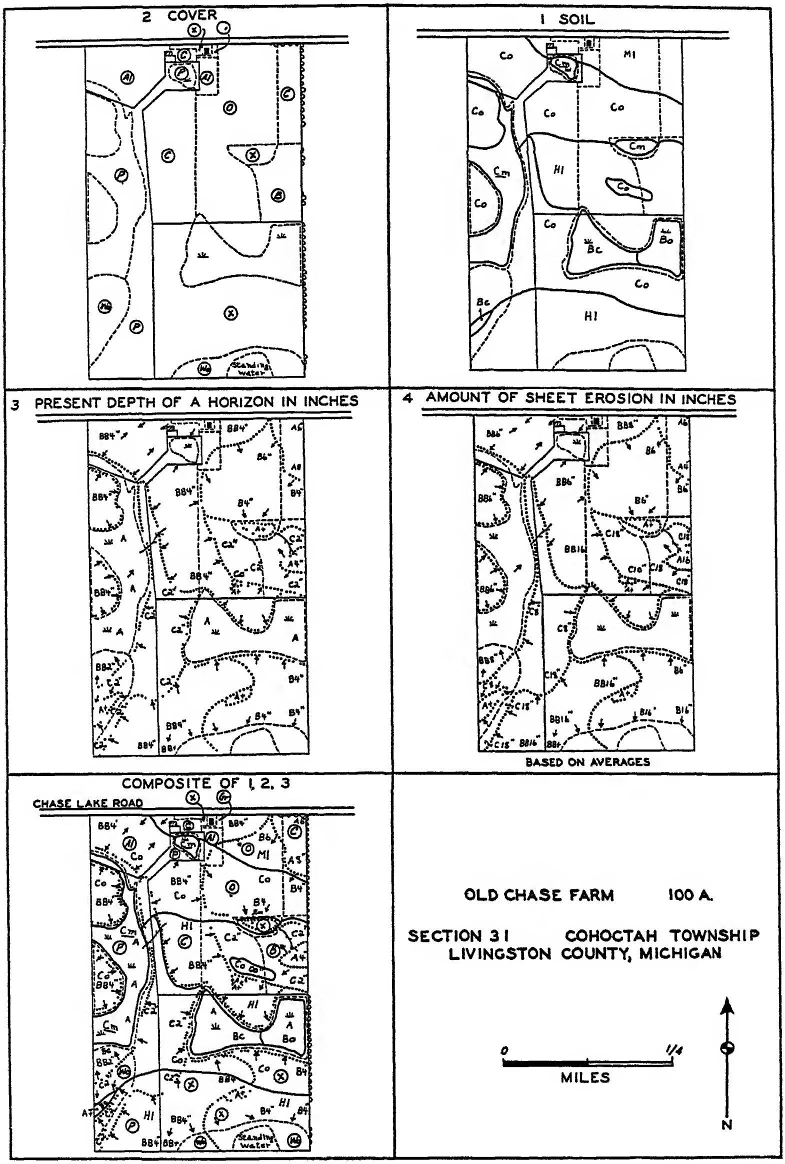

2 COVER
1 SOIL
3 PRESENT DEPTH OF A HORIZON IN INCHES
4 AMOUNT OF SHEET EROSION IN INCHES
BASED ON AVERAGES
COMPOSITE OF 1, 2, 3
CHASE LAKE ROAD
OLD CHASE FARM 100 A.
SECTION 31 COHOCTAH TOWNSHIP
LIVINGSTON COUNTY, MICHIGAN
0
1/4
MILES
N

Fig. 31

economy. Land plaster was used for fertilizer, and beans were planted each year as a cash crop. They usually produced 10 to 15 bushels to the acre soon after their introduction.

In recent times no rigid system of rotation has been practiced. Generally corn, oats, wheat, and hay follow in order, with beans occasionally planted before the wheat. Commercial fertilizer and manure are employed to enrich the soil, but yields have declined. Wheat produces so poorly that it is scarcely worth while to attempt to grow it. Oats, which constitute the main cereal crop, yield 25 to 35 bushels per acre. A herd of milch cows is kept, and 50 pigs are being raised for sale. Howell is the present trading center.

About 1900 gully erosion became noticeable, but little was done to prevent it. Few gullies are to be seen on the farm at present since earth is plowed into them as they form. The first well, which was dug by hand to a depth of 30 feet, has been deepened an additional 90 feet by drilling.

RELATIONSHIP BETWEEN LAND TYPES AND TAXATION

It is a recognized fact that the farmer has been heavily burdened by taxation. Most of it is in the form of a property tax based on the assessed valuation of his land. "The adoption of the 15-mill constitutional tax rate limitation amendment, the transfer of township roads to the counties and the almost complete shift of the support of rural highways from the property tax to motor taxes, the elimination of the state levy on property, the forced reduction of other property tax levies, the remarkable expansion in state aid for education and welfare purposes, and the forced imposition of the 3-percent retail sales tax and other new sources of revenue are some of the changes occurring during the depression that warrant the statement that there has been a tax revolution in Michigan." [5]

As an example of the verity of the foregoing statement school-tax statistics have been used. They are levied on the assessed valuation of property within each school district [6] (Fig. 32). Data on assessed valuation and the tax rate were gathered for six years of the period

[5] Cline, Denzel C., *Michigan Tax Trends as Related to Agriculture.* Agric. Exper. Station, Mich. State College, Spec. Bull. No. 301 (Feb., 1940), p. 77.

[6] The school-district map was constructed by means of material collected by H. T. Smith, "A Survey of Educational Factors of Livingston County as a Basis for Possible Reorganization." This is a master's thesis, still in manuscript, presented to the School of Education, University of Michigan.

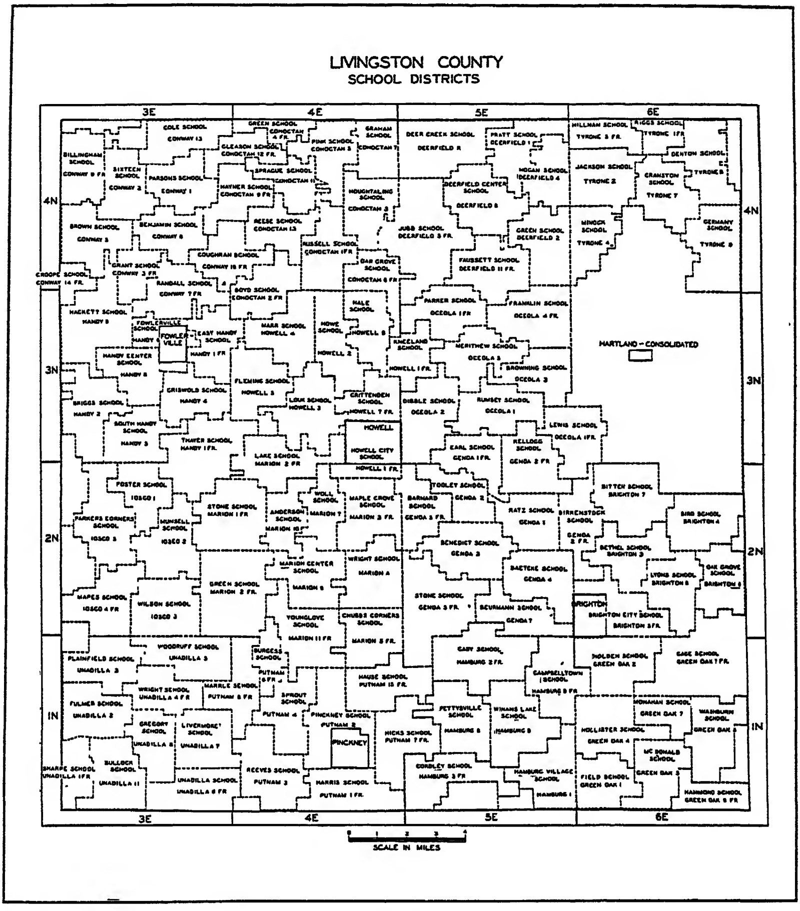
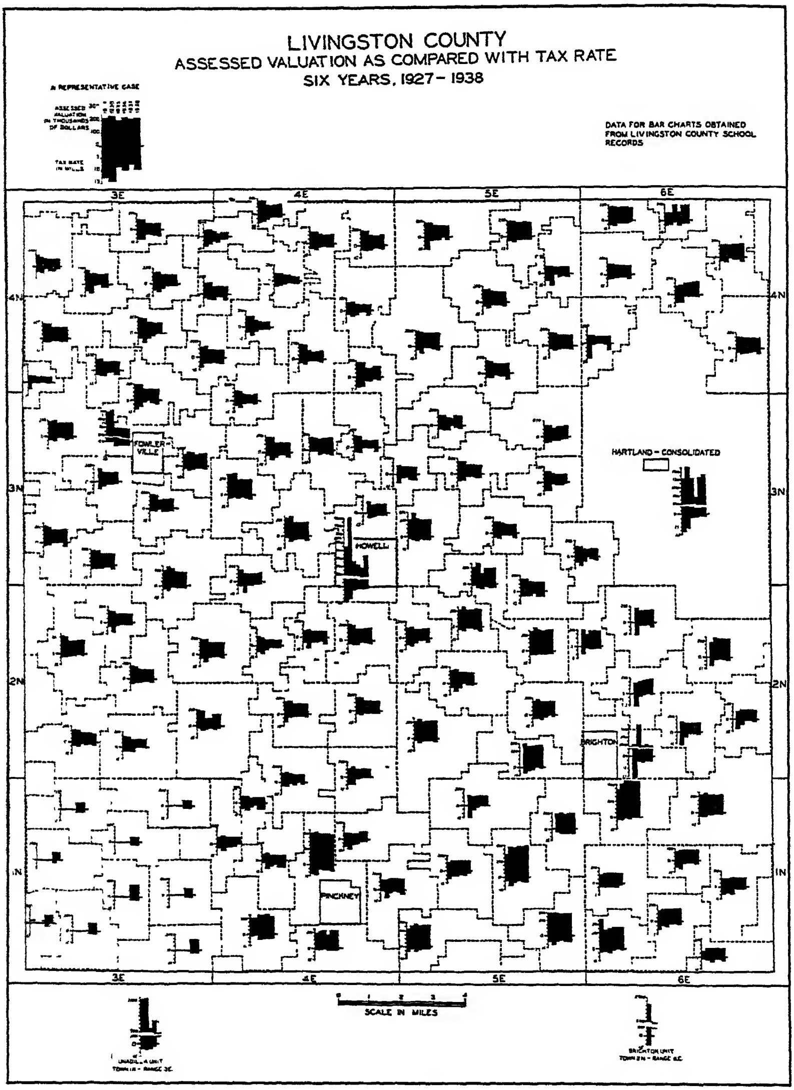


FIG. 32

from 1927 to 1938. By comparing Figure 33 with the land-type map (Fig. 17) it can be seen that the real tax load has fallen on the farmers in the poorer land types, where the land values are lowest. It costs nearly as much to maintain a school in a district composed mostly of poor land as it does in one having mostly valuable land. Thus the farmers whose income is lowest pay a greater percentage of their earnings in school taxes than do their more wealthy neighbors.

Choosing three years from the assessment figures the writer



LIVINGSTON COUNTY
ASSESSED VALUATION AS COMPARED WITH TAX RATE
SIX YEARS, 1927 – 1938
DATA FOR BAR CHARTS OBTAINED FROM LIVINGSTON COUNTY SCHOOL RECORDS
3E
4E
5E
6E
4N
3N
2N
1N
FOWLER-VILLE
HOWELL
HARTLAND – CONSOLIDATED
BRIGHTON
PINCKNEY
SCALE IN MILES

FIG. 33

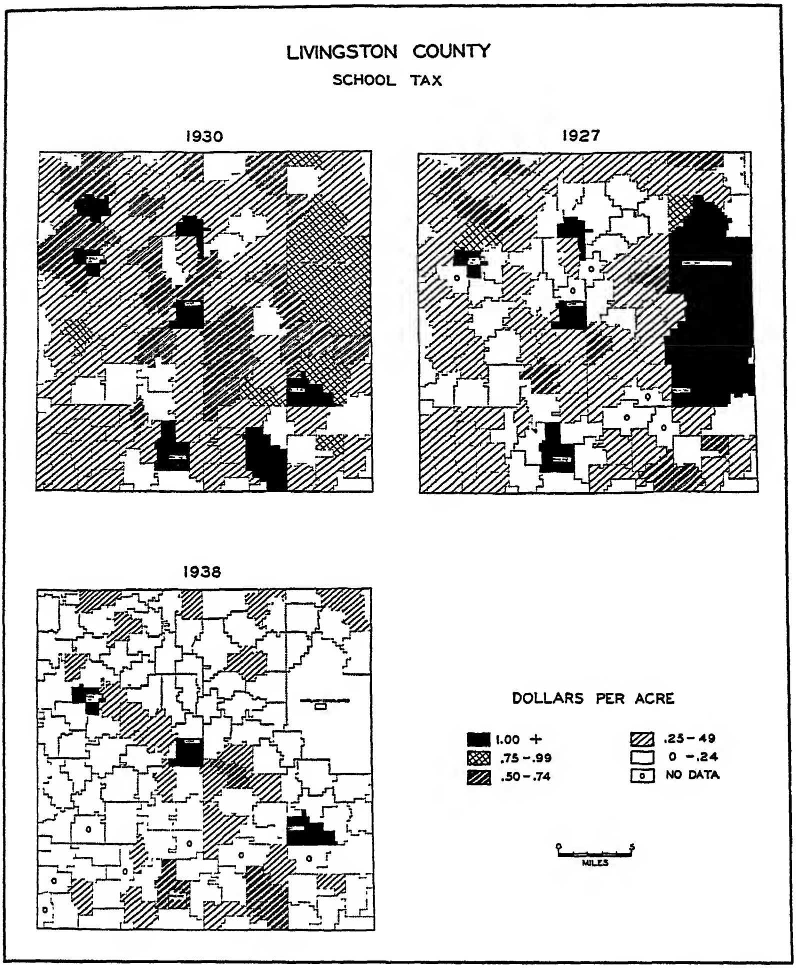


FIG. 34

carried this investigation further by computing the school tax for each district in dollars per acre (Fig. 34). The year 1927 was selected to represent conditions during predepression years; 1930, to show conditions in the early days of the depression; and 1938, to illustrate the present-day situation. Districts within the Conway land type in the northwestern part of the county will serve as an example. Agri-

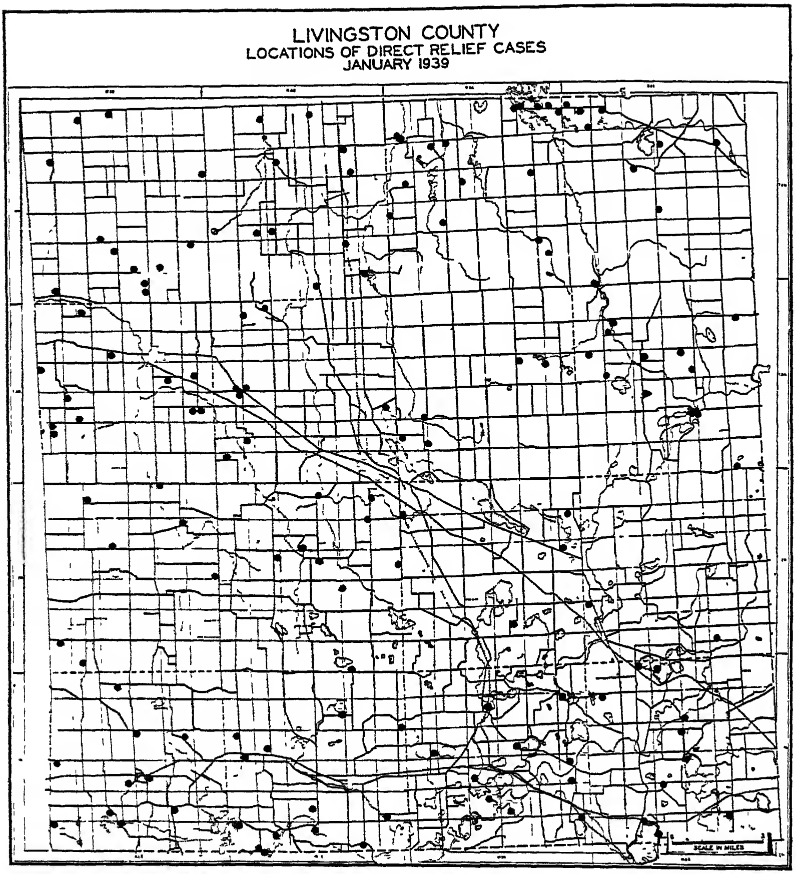


Fig. 35

culture is generally poor in that land type, yet school taxes in several of its districts for the years 1927 and 1930 fall in the relatively high-level group of 50 through 74 cents an acre. Except for areas affected by urban schools similar observations may be made in other parts of the county. It is true that there are places within the better land types which also have a high tax rate. Due consideration must be given, however, to the fact that incomes from farms in these better types far exceed those gained from farms within types less suitable for agriculture. The conclusion is that the tax load was unjustly

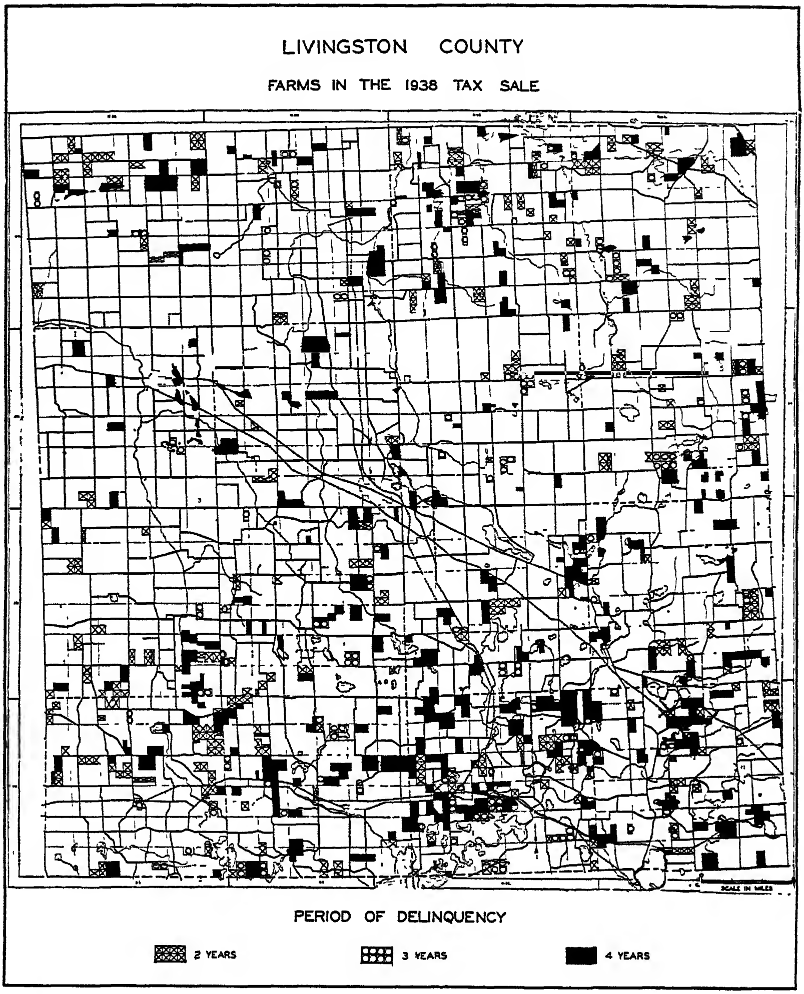


FIG. 36

apportioned. By 1938 the situation was somewhat improved. The map for that year (part of Fig. 34) indicates that taxes are greatly lower over the whole county. Most of the poor land types are now in the low-tax group, whereas land of high agricultural value is in most of the remaining high-tax groups.

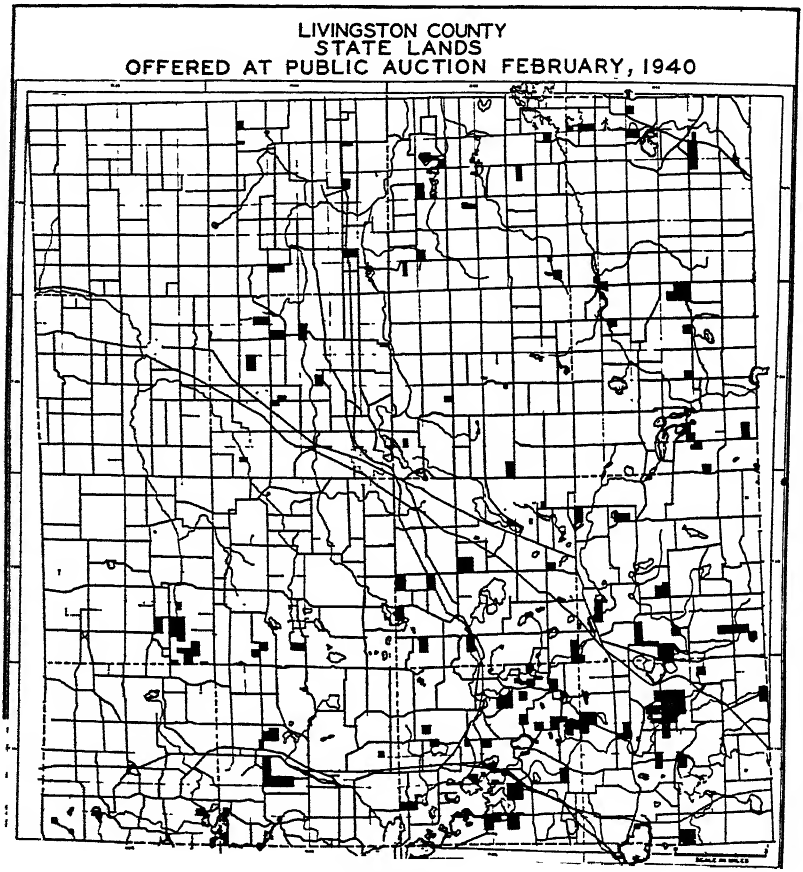


FIG. 37

RELATIONSHIPS BETWEEN LAND TYPES AND FINANCIAL ASSISTANCE TO FARMERS

Even when agricultural produce commands high prices the individual on poor land finds himself at a disadvantage in competition with his more fortunate neighbors. In a number of the Livingston County land types the possibilities of agricultural production are greatly limited. With unfavorable climatic conditions or economic depressions, such as the one just past, the farmers on poor land often find themselves in serious financial straits. A comparison of the

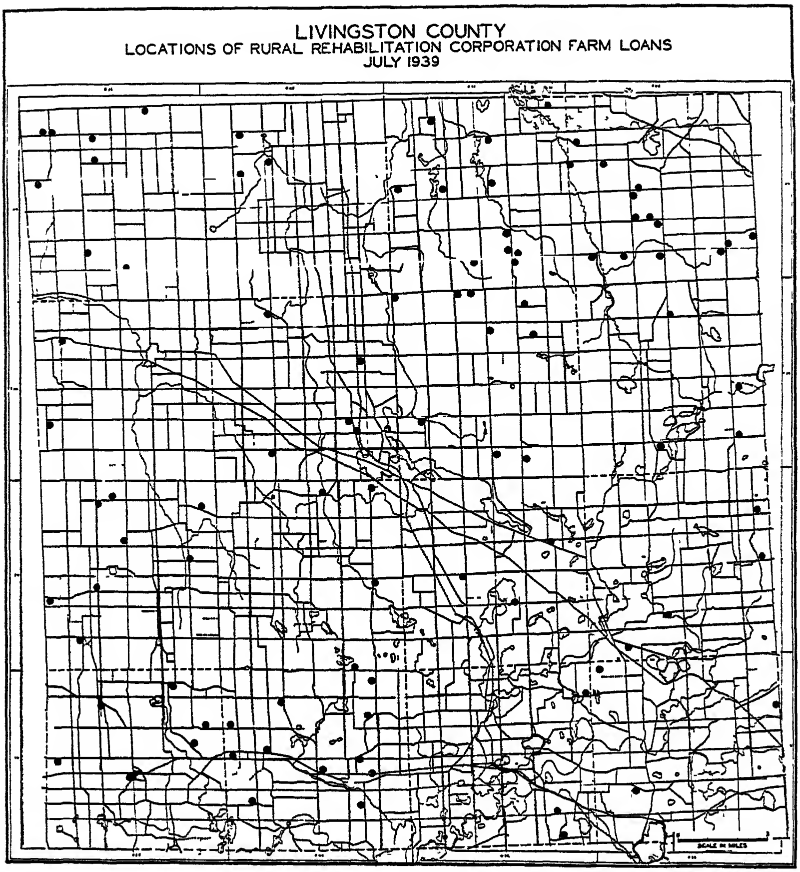


FIG. 38

map showing direct-relief cases (Fig. 35) with the land-type map (Fig. 17) makes the situation clear. It is true that these cases are not all confined to the farming population. Nevertheless, they are at least fairly representative of the distribution of rural people who are in particularly poor financial condition.

Perhaps more significant is the distribution of rural tax delinquency as indicated by the maps of farms in the 1938 tax sale (Fig. 36) and of state lands offered at public auction in February, 1940 (Fig. 37). Supplementing these illustrations are two maps show-

LIVINGSTON COUNTY
FEDERAL LAND BANK AND LAND BANK COMMISSIONER FARM MORTAGES

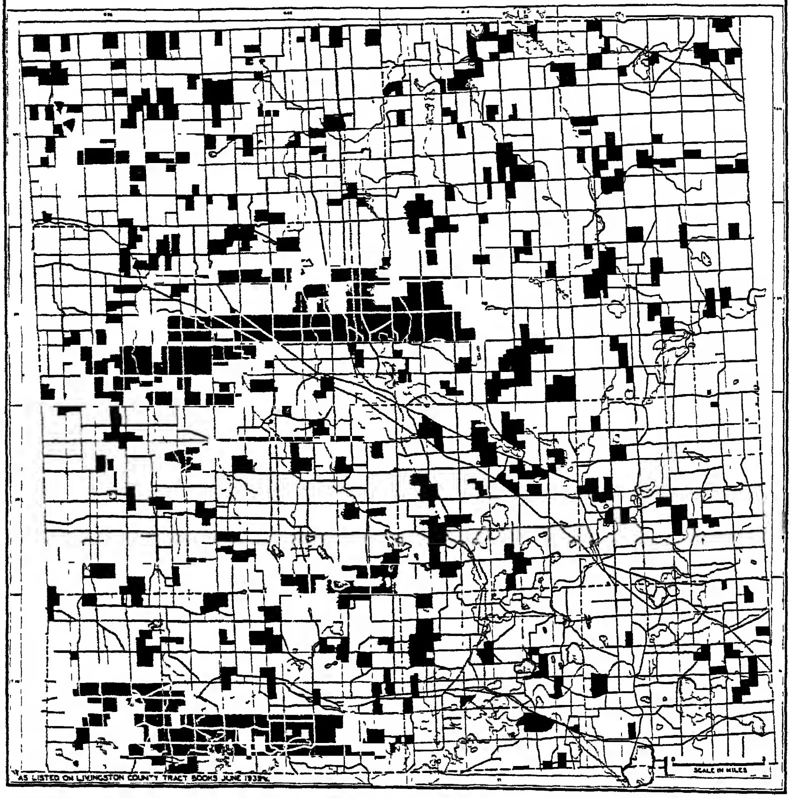


Fig. 39

ing farmland which is under financial obligation to at least one of three federal agencies. Figure 38 records distribution of rural rehabilitation farm loans during the summer of 1939; Figure 39, the locations of mortgages held by the Federal Land Bank and the Federal Land Bank commissioner in the summer of 1939. Here again can be seen the recurring pattern of conditions within the poorer land types. Table I will serve to emphasize with actual figures relationships revealed by the maps.

TABLE I

FARM MORTGAGES OF THE FEDERAL LAND BANK AND THE LAND BANK COMMISSIONER

Township	No. of acres in farms	No. of acres covered by mortgages	Percentage of acres covered by mortgages	Assessed valuation of rural land	Amount of F. L. B. mortgages	Amount of F. L. B. C. mortgages	Total amount of mortgages	Percentage of assessed valuation in both kinds of mortgages
Unadilla........ 1 N. 3 E.	22,023	3,695	16.8	$ 564,650	$ 65,300	$ 26,600	$ 91,900	16.2
Putnam......... 1 N. 4 E.	21,927	3,264	14.9	693,450	60,400	17,500	77,900	11.2
Hamburg....... 1 N. 5 E.	21,638	2,182	10.1	1,115,475	34,200	14,200	48,400	4.9
Green Oak...... 1 N. 6 E.	21,009	1,112	5.3	1,143,700	14,800	11,500	26,300	2.3
Iosco........... 2 N. 3 E.	22,331	2,796	12.6	663,900	41,500	12,600	54,100	8.2
Marion......... 2 N. 4 E.	22,600	2,434	10.8	741,325	39,500	29,600	69,100	9.3
Genoa.......... 2 N. 5 E.	21,895	3,695	16.9	1,152,300	70,400	20,900	91,300	7.9
Brighton........ 2 N. 6 E.	20,209	1,443	7.1	1,025,300	19,500	15,100	34,600	3.4
Handy.......... 3 N. 3 E.	21,067	4,172	19.7	1,497,220	113,600	48,200	161,800	10.8
Howell......... 3 N. 4 E.	20,840	3,681	17.7	934,350	65,300	33,500	98,800	10.6
Osceola......... 3 N. 5 E.	23,289	3,908	16.8	890,900	68,500	33,900	102,400	11.5
Hartland........ 3 N. 6 E.	23,456	2,190	9.4	791,700	51,500	13,100	64,600	8.2
Conway......... 4 N. 3 E.	23,930	4,037	16.9	863,700	81,600	47,800	129,400	14.9
Cohoctah....... 4 N. 4 E.	24,450	2,899	11.8	878,200	70,700	32,800	103,500	11.8
Deerfield........ 4 N. 5 E.	23,505	3,237	13.8	727,900	59,800	32,200	92,000	12.6
Tyrone......... 4 N. 6 E.	22,257	2,595	11.7	679,850	51,800	21,500	73,300	10.7
COUNTY......	356,426	47,340	13.0	$14,363,920	$908,400	$411,000	$1,319,400	9.2

SUMMARY

Agricultural problems in Livingston County, Michigan, are due not only to the qualities of the land itself, but also to the uses to which the land has been put and to the ways in which it has been exploited or abused. The history of settlement is but a prelude to the more intensive study of the development of agriculture and of its problems. This history is readily reconstructed from the records of actual settlement in the early part of the nineteenth century. The origin of settlers is inferred from house types and confirmed from local histories and the tract book of the General Land Office. Subsequent improvements and changes in houses are related closely to the sequences of agricultural practices which have been outlined in Part II of this paper. The development of erosion and concomitant changes in land use have resulted in the present impoverished condition of agriculture in much of the county. It has been shown, too, that taxation has played an important rôle in this history. The story is not completed here, but the materials presented may aid in the formulation of plans for the better use of the land and for an integration of the farmers of Livingston County in an economy for the United States as a whole that will give them a better living than has been possible in the recent past.

University of Michigan

EARLY MAPS OF ANTARCTIC LAND, TRUE AND FALSE *

WILLIAM HERBERT HOBBS

IT HAD not been my intention to make reply to the twenty-one-page review by Dr. A. R. Hinks [1] of my monograph on Antarctic discoveries.[2] My view has been, and still is, that the matters treated have been fully covered by me in the original monograph, the half-page erratum sheet for minor corrections issued soon after, and two articles subsequently published.[3] I see no reason to alter because of the review my statements concerning any of the vitally important matters which were discussed. I make reply only to the charges of falsification.

At the top of page 311 of the review Dr. Hinks states: "Professor Hobbs begins by attributing to Bransfield first a share in and later the full authorship of the indifferent map . . . which Foster drew in January 1820 at Valparaiso to illustrate the discoveries of William Smith in 1819. It is so clear that Bransfield had nothing to do with this map that the attempts to father it upon him and the pretence that it represents his voyage in the *Williams* of January and February 1820 must be called deliberate misrepresentation."

Further (p. 313), Dr. Hinks cites as the title of this map: "A View of the Land Discovered by William Smith of the Brig Williams of Blyth Feby. 1819 and taken possession of in the name and on behalf of His Britannic Majesty George III and called New or South Shetland. Henry Foster, Mid^{n} H.M.S. Creole Jany. 1820 . . . ." He later adds: "Professor Hobbs reproduces the map on his

* Reply to a review by the Secretary of the Royal Geographical Society which was refused publication by that Society.

[1] H[inks], A. R., "On Some Misrepresentations of Antarctic History," *Geog. Journ.*, 94 (1939): 309–330.

[2] "The Discoveries of Antarctica within the American Sector, as Revealed by Maps and Documents," *Trans. Am. Philosoph. Soc.*, N. S., 31, Part I (1939): 1–71, pls. I–XXXI, figs. 1–10.

[3] Hobbs, William H., "The Pack-Ice of the Weddell Sea," *Ann. Assn. Am. Geog.*, 29 (1939): 159–170, map; *idem*, "The Discovery of Antarctica: a Reply to Professor R. N. Rudmose Brown," *Science*, 89 (1939): 580–582, map.

Plate I (top), ignores the title, signature, and date January 1820, and labels it Map of the South Shetland Islands by Smith and Bransfield 1819 and 1820."

The title cited refers to a "view" by Foster on the same sheet as the map. This, and not a desire deliberately to misrepresent, was my reason for ignoring it, with its signature and date. It is not definitely known who drew the original map of which this is possibly a copy with notation in the handwriting of Foster,[4] but it corresponds with that authorized for publication in the reports [5] of Smith's cruise, and it can be referred to as the Smith map or, for reasons given below, the Smith–Bransfield map. In the introduction to the extracts which were published in the *Literary Gazette* it is stated that these extracts came in a packet sent from Buenos Aires, and that "There was a map with the packet, but it appears, (with the exception of Dalrymple's chart) to be similar to that in Brewster's Philosophical Journal,[6] *which may be referred to.*" [7] Dr. Adam Young also, in his authentic account of the Bransfield cruise, *made use of this same map for reference in place of publishing any new map,* and as there is no other published map of the Bransfield cruise, I have called it the Smith–Bransfield map, for Young's account indicates that the Bransfield cruise was made to confirm Smith's discoveries.

The authentic account of the Bransfield cruise was written by the medical officer of H.M.S. *Slaney* (Young) and was completed at Valparaiso May 26, 1820, or shortly after his return from the cruise (April 14). It was published in the *Edinburgh Philosophical Journal.*[8] There has never been any question of the authorship, and

[4] Foster was not on the cruise with Smith, but was attached to H.M.S. *Creole* stationed at Valparaiso when Smith arrived there. The sketch was therefore made either from descriptions or from some map drafted on board. As regards the map, in a news item sent from Valparaiso to the London *Literary Gazette* (4 [1820] : 524) it is stated: "The only draughtsman in the station, competent to perform the scientific part of the investigation, was Mr. Bone, a son of the distinguished artist of that name; he accordingly went in the Williams and made the drawings of the coast."

[5] Extracts from Smith's log harmonious with the authentic account (*Edinburgh Philosoph. Journ.*, 3 [1820] : 367–380) appeared in the London *Literary Gazette* of October 14, 1820.

[6] Dr. Brewster was chief editor of the *Edinburgh Philosophical Journal.* Dalrymple's chart of Cape Horn was reproduced on the same plate as the Smith map.

[7] Italics mine.

[8] "Notice of the Voyage of Edward Barnsfield, Master of His Majesty's Ship Andromache, to New South Shetland," *Edinburgh Philosoph. Journ.*, 4 (1821) : 345–348.

it is stated in the article that Young accompanied the expedition as its medical officer.

This Smith–Bransfield map has been reproduced in many atlases subsequent to the publication of Young's report, and in all these the land mass or continent described is called New South Shetland. Among these publishers were Brué, Paris, 1821; Arrowsmith, London, 1821; Tanner, Philadelphia, 1821 and again in 1823; Stieler, Gotha, 1822; Reichard, Nuremberg, 1822 and again in 1825; Schou, Copenhagen, 1822; Reimer, Berlin, 1824; Weiland, Weimar, 1824; Finley, Philadelphia, 1824; Lichtenstein, Berlin, 1825; Hydrographical Office, Madrid, *ca.* 1825; and Huot, Paris, 1831.

The maps which Dr. Hinks exploits as the genuine ones, but which I have designated as false, were not published, and naturally they were not reproduced. The "Bransfield" map showed Antarctic land, which it named "Trinity Land," with a near-by island named "Tower Island." Though both maps were by their titles ascribed to British navigators with Bransfield, a Royal Navy Master, and both were deposited in the Hydrographical Office of the Admiralty, neither the "Goddard" nor the "Bransfield" map was issued by that office, nor in fact, by anyone. Instead, the Admiralty Chartseller, R. H. Laurie, in 1822 discredited the "Bransfield" map in a published statement [9] and used the Palmer Land map. In 1824 the Hydrographical Office of the Admiralty printed the Palmer Land map on an official chart.[10] Following at once the Admiralty's official use of Palmer Land atlas makers all over the world copied this map to replace the erroneous South Shetland land mass or continent of Bransfield, which was a full degree farther to the north. Some of these publishers were Gardner, London, 1825; Brué, Paris, date uncertain; Denaix, Paris, 1828; Hall, London, 1830; Arrowsmith, London, 1832; Lizar, Edinburgh, 1842; Black, Edinburgh, 1844 and again in 1847.

Not until 1825 was the name "Trinity Land" printed upon any published map. It then appeared on the false map by James Weddell, but was not ascribed to Bransfield, was quite unlike the Antarctic land of the "Bransfield" map, and was referred to as "laid down from

[9] "The *Trinity Land* and *Tower Island* of the first charts in about $63\frac{1}{2}°$ South and $60\frac{1}{2}°$ West are given up as imaginary . . . ." George Powell, *Notes on South Shetland* . . . (London, 1822), p. 6.

[10] See *Science*, 89 (1939): 581.

the information of respectable commanders of ships." The larger of Weddell's two wholly different maps of "Trinity Land" showed a trilobate schematic pattern convex to the north (the Antarctic coast of the "Bransfield" map was concave to the north). The year 1825 thus marks the first appearance of "Trinity Land" on any known published map, and it was thereafter very widely reproduced from Weddell's larger map in atlases all over the world.[11]

Another outright charge of falsification on my part appears in Dr. Hinks's article, on page 311. He there states:

> Professor Hobbs denounces as a palpable forgery, having himself falsified the photograph of it he obtained from the Admiralty by cutting out a small piece, about one-twelfth, so as to evade the title, the author's name and the date, and sticking on pieces of the original divided border with the longitude shifted five degrees.
>
> This is the crux of the whole matter. The positive evidence that Bransfield discovered the Antarctic Continent is: first the chart with his signature which is in the Hydrographic Office (Map C [12]); secondly the account of the voyage in the *Literary Gazette* (Document III [13]); and thirdly the confirmation in Smith's map [14] drawn by Goddard (Map F).

Now as to the alleged falsification. The original map photostat as furnished me by the Hydrographical Office of the Admiralty is 14 by $21\frac{1}{2}$ inches, and the part reproduced in the "falsified" map published in my monograph is $3\frac{1}{2}$ by 4 inches. This was accomplished "by cutting out a small piece, about one-twelfth." Dr. Hinks fails to mention that the eleven twelfths omitted was largely blank paper, or that my map is complete for all that is germane, with the exception of the title printed near the edge of the map and a quite recent notation in the corner, "Received from the Record Office 3rd January 1822." [15]

As regards the title, I much desired to include it, though this would have required a separate plate, and the cost of my map illustrations was already excessive. The omitted title claims that on February 19, 1819, Smith made the discoveries represented upon

[11] Hobbs, Pl. XIX of article cited in note 2.

[12] Never published and wholly at variance with the authentic report of the cruise by Young and with the map which he cites.

[13] Anonymous and at variance with the authentic report.

[14] This makes Smith discover the Antarctic land on his cruise of February 19, 1819.

[15] In 1913 this map was published nearly complete in the *Geographical Journal* (42 : 365–370), but *without* this notation. We must therefore conclude that the notation is a later addition.

the map, whereas upon that date, according to the authentic account,[16] he was not even sure that what he saw in the distance was land. The only thing that is honest on this map is the track of the *Williams*. Smith's real map as published with his article was based, not on his February cruise, but on his October cruise of the same year. Even then he could not possibly have made these discoveries, since his map shows that his ship was always on the north side of the islands. If favored by mirage, the Antarctic land might conceivably have "loomed up," but in that case it would have been brought much nearer and not shown in approximately its correct position as later determined. The theory of a mirage could not, however, have accounted for the mapping of the south shores of the islands, which in 1819 would have required the use of our modern aircraft.

To show the latitudes and longitudes on the map, which I reproduced without the surrounding blank paper, it was necessary to paste the divided borders along two sides of the map, and on one of them a shift of five degrees unfortunately occurred, though in the meridians only. This had, however, nothing to do with the questions under review.

It is interesting to note that the Goddard map resembles the Woodbridge Palmer Land maps which were published at Hartford on September 28, 1821,[17] and could easily have been in London weeks before the date of January 3, 1822.

UNIVERSITY OF MICHIGAN

[16] Reference given in note 5.
[17] Hobbs, as cited in note 2.

A COVER MAP BASED ON AIR PHOTOGRAPHS, EMMET COUNTY, MICHIGAN

OMAR H. LOVEJOY

A STUDY of tax delinquency and related problems in Emmet County, Michigan, suggested the need of a practical cover survey which might be used in connection with further investigations. Federal air photographs, obtainable from the Agricultural Adjustment Administration of the Department of Agriculture, have made feasible a cheaper yet adequate method of mapping land use. It is the purpose of this paper to present the early results of an experiment in land inventory based primarily on air photographs.[1]

The staff of the summer camp of the Department of Geography, University of Michigan, has worked in Emmet County for two seasons and has done a great deal of cover mapping. It was undertaken by field crews using plane tables, compasses, and alidades. Air photographs of the county, which became available in August, 1939, offered an opportunity to begin the new experiments.

The utility and value of photographs quite naturally depend upon the extent to which they can be accurately interpreted or "translated." It is to be noted that in this experiment interpretation had to be made by means of field maps which were not specifically devised or planned for correlation with air photographs. When a new system of mapping is organized chiefly to correlate field data with photographs, the technique will become much more effective.

The photographs obtained from the Department of Agriculture cover the whole county. Successive pictures were taken from an altitude of about 17,000 feet while the airplane was flying in what are called "flight lines." There are twenty-seven flight lines in the county. The photographs overlap considerably, so that it is possible to get complete coverage by using every other picture in each flight.

[1] Two other papers on airplane photographs, both by H. P. Underhill, have appeared in Academy volumes. They are as follows: "Notes on the Assembly of Airplane Photographic Mosaics," 20 (1934): 415–433. 1935; "Notes on Reading Air Photographs," 21 (1935): 285–291. 1936.

Each photograph is about seven by nine inches and has a scale of 1:20,000, or three inches to the mile. Occasionally pictures are not exactly to scale, but the errors are relatively negligible. A problem arose in securing a map on which individual photographs could be fitted. Only a county road map, based on an early highway survey, was available, yet in spite of inaccuracies it was entirely possible to match photographs and to group them into a map with a minimum of error.

The pictures were fitted together in eight contiguous groups, each containing one or two townships. Then the road pattern of each group was copied by means of tracing paper. With the use of a light table each photograph was then refitted under the appropriate road tracing, which made possible an accurate drawing of the more detailed vegetation boundaries. The field sheets mentioned previously served as an aid in interpretation, which was facilitated by the use of a low-powered stereoscope.

A system of symbols was adapted from those of the Michigan Land Economic Survey. It was designed to indicate cover in areas of hilly uplands, sand dunes, sandy plains, and swamp lands, and also the cleared operated and the cleared abandoned lands. Size of stocking is shown by three general classes, 0–3, 3–6, 6–9 inches; the density of the stand, by the small letters *h*, *m*, *s*, for "heavy," "medium," and "scattered," respectively. The eight maps, done first in pencil, were then inked, blue-lined, and, finally, colored.

A legitimate question can be raised in regard to the possibility of reading and accurately interpreting air photographs in such detail. Can one consistently recognize the stocking of the various species and the density differences? Experience is still too limited to give a positive answer to this question. It is doubtful whether all the swamp vegetation boundaries on the map (Fig. 1) have been correctly drawn. A swamp of dominantly cedar cover has definite limits, which are easily detected, but boundaries within swamp areas containing a mixture of spruce, balsam, cedar, and poplar are not readily distinguishable. It is also difficult to determine limits in terms of stocking and density where gradual changes occur. On the other hand, marked differences, such as those between "hardwood 0–3 scattered" and "hardwood 6–9 heavy" are readily noted. Differences in texture usually indicate operated farmland and distinctly nonoperated or abandoned lands. Much of the so-called

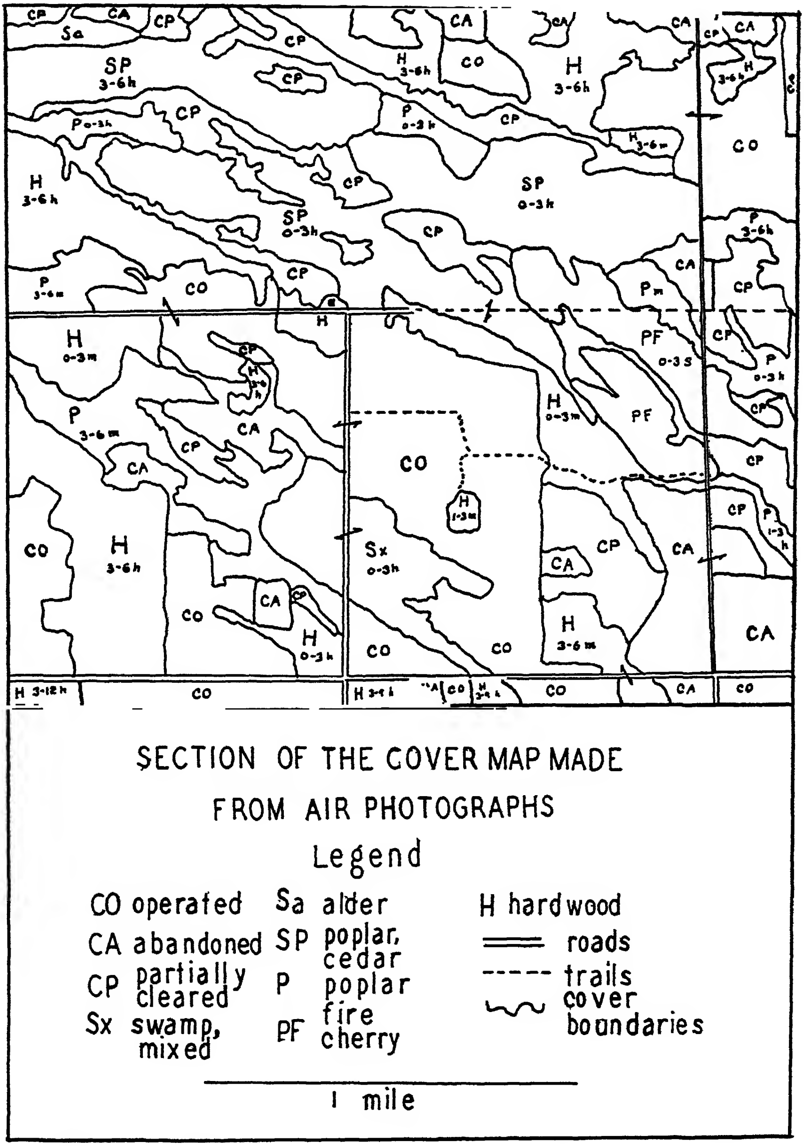

SECTION OF THE COVER MAP MADE
FROM AIR PHOTOGRAPHS
Legend
CO operated
CA abandoned
CP partially cleared
Sx swamp, mixed
Sa alder
SP poplar, cedar
P poplar
PF fire cherry
H hardwood
roads
trails
cover boundaries
1 mile

FIG. 1

nonoperated land is only semiabandoned, however, which makes difficult the problem of accurate demarcation of all abandoned lands. Another difficulty in detecting cover differences arises where shadows occur in steep hilly areas. Some manner of field investigation of doubtful areas will probably be found which will eliminate such inaccuracies.

The use of this inventory technique has produced a map which at least portrays the various patterns of vegetation and cleared lands. They can easily be correlated with land types and with areas in which tax delinquency is prevalent.

As has already been indicated, this method of cover mapping calls for two separate uses of the individual photograph: (1) in the field, to facilitate collection of original data; and (2) in the office, where it is employed for reference in drawing boundaries and, grouped with other photographs, as the basis for the completed map.

It is felt that the results of this experiment with photographs justify further investigation and an effort to create a definite technique. It may well be that developments will lead to a system of mapping which will supersede the more costly method first established by the Michigan Land Economic Survey.

University of Michigan

THE AGRICULTURAL PATTERN OF THE EASTERN HIGHLAND RIM PLATEAU OF TENNESSEE

H. THOMPSON STRAW

NO MATTER where one stands in the Central Basin of Tennessee the valley appears to be surrounded by a line of hills (Pl. I, Fig. 1). Actually, this is the serrated edge of the escarpment of the Highland Rim Plateau, a tableland which rises about 300 feet above the general level of the Basin. In Tennessee this tableland is divided according to its relation to the Central Basin into the eastern, northern, and western plateaus. Thus the Eastern Highland Rim Plateau is the undulating upland, about 25 miles wide and 125 miles long, which extends from the higher Cumberland Plateau on the east and ends in the fringe of high hills which bounds the eastern edge of the Central Basin (text Fig. 1).

When viewed in relation to the adjacent areas the region is essentially one of transition. In elevation it occupies a position midway between the lower Central Basin and the higher Cumberland Plateau. Its soils, although by no means uniform, in general lack the fertility of those derived from the phosphatic limestones of the Central Basin, but are in turn more fertile than the sandy soils of the Cumberland Plateau. The economic and social position of its people might also be classified as transitional between the two adjacent areas. The Basin was developed largely along traditional Southern lines based on plantation economy. In the Cumberland Plateau the majority of the settlers failed to rise much above the level of bare subsistence. The people of the Eastern Highland Rim Plateau belong to neither of these groups, but hold an intermediate position. They are descendants of the group of settlers known as the yeomanry,[1] independent farmers who operated their farms

[1] Den Hollander, A. N. J., "The Tradition of 'Poor Whites,'" Chap. 20, in *Culture in the South*, edited by E. T. Couch. Chapel Hill, N. C.: University of North Carolina Press, 1934.

without the aid of much slave labor. The transitional position of the region is shown also by the acreage in farms, by the amount of improved lands, and by the crop yields. Here, too, the region is intermediate between the Central Basin, which is largely a succession of field and improved pasture with only occasional wood lots and cedar glades, and the Cumberland Plateau, with its small clearings scattered throughout an extensive area of forest and cutover land.

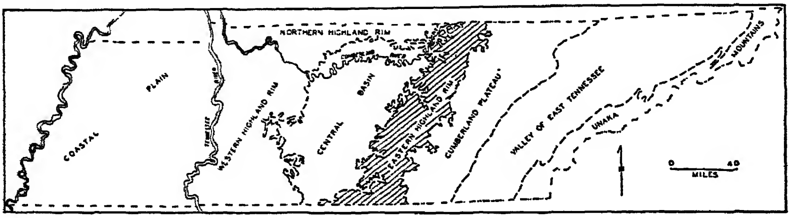


FIG. 1. Surface map of Tennessee, showing location of Eastern Highland Rim Plateau

THE LAND

The gently rolling surface of the Eastern Highland Rim Plateau represents a stage of peneplanation arrived at during Tertiary times. On it are exposed rocks mainly of Mississippian age. Those of early Mississippian age, which are near the western margin and of which the Fort Payne chert is an example, consist of limestones filled with chert and a porous siliceous cement (Fig. 2).[2] Those of a later Mississippian age, which are near the eastern part of the Plateau and of which the St. Louis limestone is an example, consist of much purer limestones, usually massive and fine-grained, with only relatively few beds of chert.

Two other groups of rocks are to be found on the Plateau. The first comes to the surface in but few places. It is the Chattanooga shale which underlies the Fort Payne chert (see cross section in Fig. 2). Since it is soft and weathers easily it is exposed only at the side of the Plateau facing the Central Basin or along the banks of streams which have cut deeply enough into the Plateau to reach it (Pl. I, Fig. 2). The second group of rocks is mainly of Pennsylvanian

[2] For a more detailed report of the stratigraphy of the region see R. S. Bassler, *The Stratigraphy of the Central Basin of Tennessee*, Bull. 38, pp. 133–162. Nashville, Tenn.: Division of Geology, 1932.

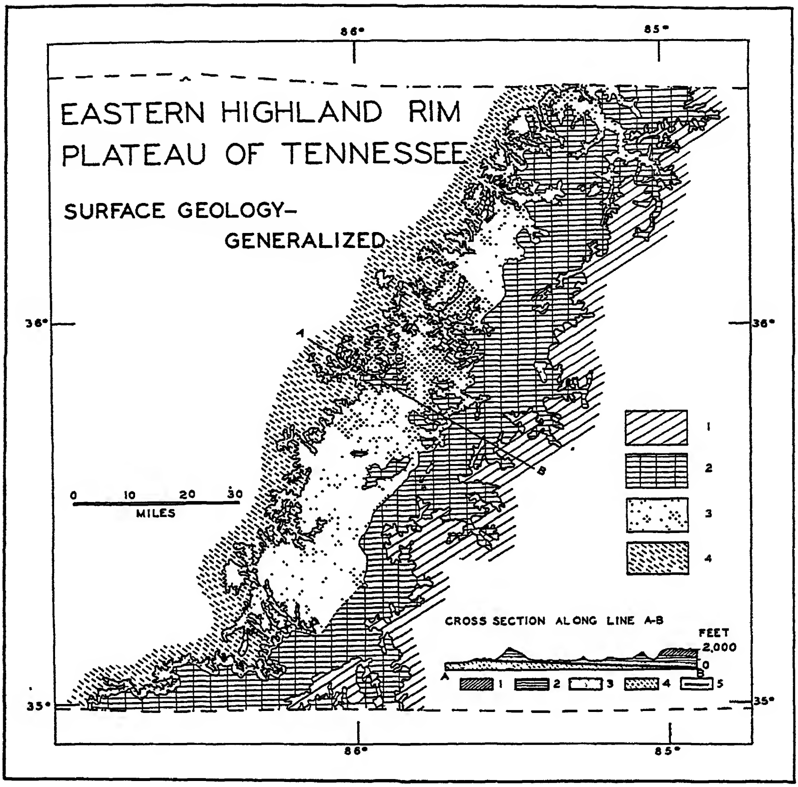


FIG. 2

KEY TO SYMBOLS FOR BOTH MAP AND CROSS SECTION

1. Pennsylvanian strata
2. Upper Mississippian strata — Bangor and St. Louis limestone in the south and Newman limestone and Pennington shale in the north
3. Lower Mississippian strata — Fort Payne chert in the south and Waverly formation in the north
4. Pre-Mississippian rocks
5. Chattanooga shale

age. These comprise the Cumberland Plateau, many outliers of which form the flat-topped hills that are especially numerous in the northern part of the region.

The type of surface and the amount of local relief are well correlated with the outcropping of rocks. On the lower Mississippian

strata the surface is usually flat to gently rolling. In some areas, especially if underlain by a clay hardpan, the problem of drainage is a serious one (Pl. I, Fig. 3). Soil erosion, except on the few areas where the slope is unusually steep, is not so important a problem as in the area of upper Mississippian rock. Here the relief is greater,[3] since karst development augments the action of river erosion (Pl. II, Fig. 1). The greatest relief is usually associated with the escarpment and outliers of the Cumberland Plateau, where the capping layers of the Pennsylvanian strata resist river cutting but are eroded by the solution of the Mississippian rock which underlies them. The result is flat-topped mesa-like hills with steep sides. Outliers are most numerous in the northern part of the region. There are, however, two other factors which help to explain the extreme hilliness here. The first is a series of small anticlines, which usually have a maximum elevation of about a hundred feet. The second is the more extensive river erosion, owing to the location near the Cumberland River (Fig. 1) and its tributaries.

The majority of the soils of the Eastern Highland Rim Plateau are residual. During the present cycle the rivers, which are generally youthful or in the earliest stage of maturity, have deposited almost no alluvium.[4] These residual soils are young enough to have derived most of their characteristics from parent material[5] and hence they, like the surface features and local relief, are usually related to the underlying strata of rock. Three longitudinal soil belts can be recognized. To the west on the lower Mississippian strata are developed the siliceous, rather infertile "Barrens-type" soils, which range in color from light tan to a light gray that borders on white and which are usually filled with chert fragments. Farther to the east and on the upper Mississippian strata are the more fertile limestone soils,

[3] For a quantitative discussion of the local relief of these areas see H. Thompson Straw, "The Relative Relief of the Eastern Highland Rim Plateau: a Study in the Cartographical Presentation of Surface Configuration," *Journ. Tenn. Acad. Sci.*, 15 (1940): 372–380.

[4] During the previous cycle extensive alluvial flats were developed along the courses of the present-day streams. An example is shown in type study A (Fig. 6). These areas of old alluvium are usually of superior soil.

[5] For a more detailed picture of soils see C. F. Marbut, "Soils of the United States," Part III of *Atlas of American Agriculture*, pl. 5, sec. 7, p. 44. Washington, D.C., 1935. For an even more detailed study of the relationship of soil and surface geology see C. S. Waldrop, "Soil Survey of Putnam County, Tennessee" (Advance Sheets — *Field Operations of the Bureau of Soils, 1912*). Washington, D.C., 1914.

mostly red to reddish brown. A third soil belt may be recognized lying adjacent to the Cumberland Plateau. Here a mixture of the red clay of the upper Mississippian limestone and of the yellow sand from the Cumberland Plateau appears.

To summarize, three broad longitudinal soil and surface belts may be discerned. To the west are "the Barrens," flat to gently rolling, with light-colored rather infertile soils. Soil depletion and, in some areas, poor drainage are the problems faced by the farmer here. East of the Barrens is the red-soil area, gently rolling to hilly. The soil is darker and far more fertile, but there is a continual problem of soil erosion. Gullying, especially near the streams or about well-developed sinkholes, is common (Pl. II, Fig. 2). East of the red-soil area and adjacent to the Cumberland Plateau is the area of steepest slope and greatest relief. Its soil, of medium fertility, is generally somewhat coarser than that of the red-soil area, but the slopes are so steep that coarseness of texture does not save it from erosion.

THE AGRICULTURAL PATTERN

Despite the clear-cut division of the Eastern Highland Rim Plateau into these three belts of surface and soil, there is but little discernible correlation between them and the utilization of the land. The percentage of land in farms is high, averaging from 70 to 80 for much of the area (text Fig. 3). The entire region is essentially one of agriculture, and other land uses occur only on a small scale. Minerals do not exist in sufficient quantities to form the basis of an extensive land use, and the exploitation of forest resources has always been on a small scale and carried on by individual farmers. Urban land use is unimportant, as is indicated by the fact that the largest city in the region, Tullahoma, has a population of barely over four thousand. With agriculture the dominant occupation, with the poorer nonarable land of the region, such as valley slopes, often intermingled with land of better grades, thus necessitating its inclusion in farms, and with a population dense enough to demand virtually all potentially arable land it is small wonder that so large a percentage of the total area is in farms. It will be noted that there is little correspondence between the distribution of farmland and the general soils-surface pattern. As a rule, only in the coves of the Cumberland escarpment and in the outliers of the Cumberland

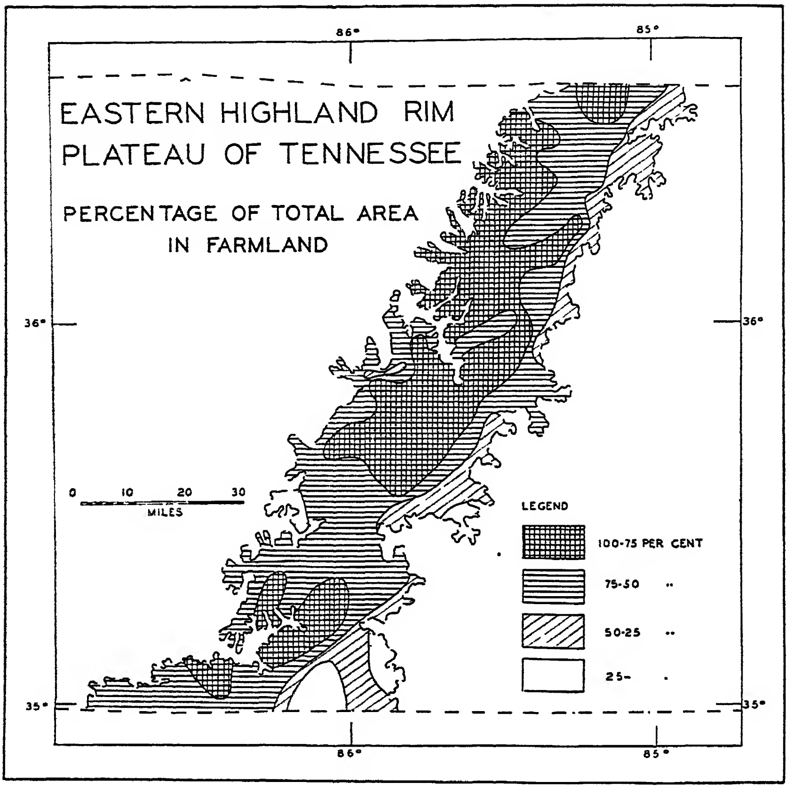


FIG. 3

Compare with Figure 2 and note the small correlation that exists

Plateau, where the slope is steep enough to make farming impractical, does the percentage of farmland drop below 50.

Like the percentage of total area in farms, the percentage of farms in improved land seems unusually high when the general fertility of the region is considered (Fig. 4). Unimproved land consists largely of that which was originally deemed too steep to clear, scattered areas of wood lot and areas which, although once cleared, were found to be so definitely submarginal that they have been allowed to return to their original forested condition. A somewhat closer adjustment can be seen between improved land and the slope

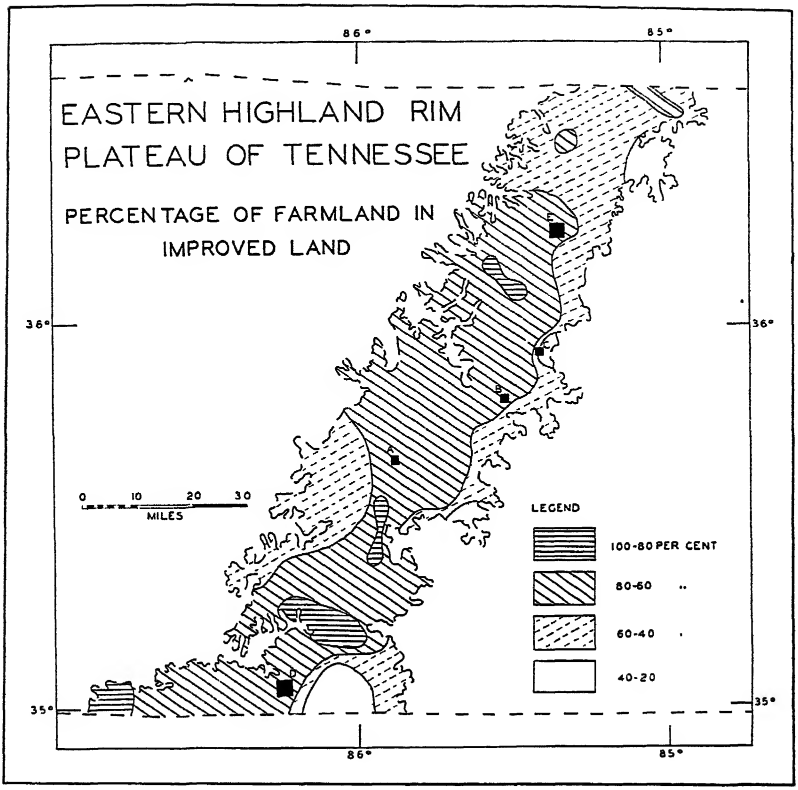


FIG. 4

Compare with Figure 2 and note the slightly better correlation than that between Figures 3 and 2

and fertility than could be discerned in the distribution of farmland (cf. Figs. 4 and 2). An extensive area having a low percentage of improved land occurs near the western border of the region, which coincides with some of the poorest soils (known locally as "the Flatwoods") that occur in the Barrens. Other areas having a low percentage of improved land are found near the escarpment of the Cumberland Plateau and are coincident with outliers, as in the southeastern part of the region. The large area to the north is associated with the section of greater local relief, the result of a series

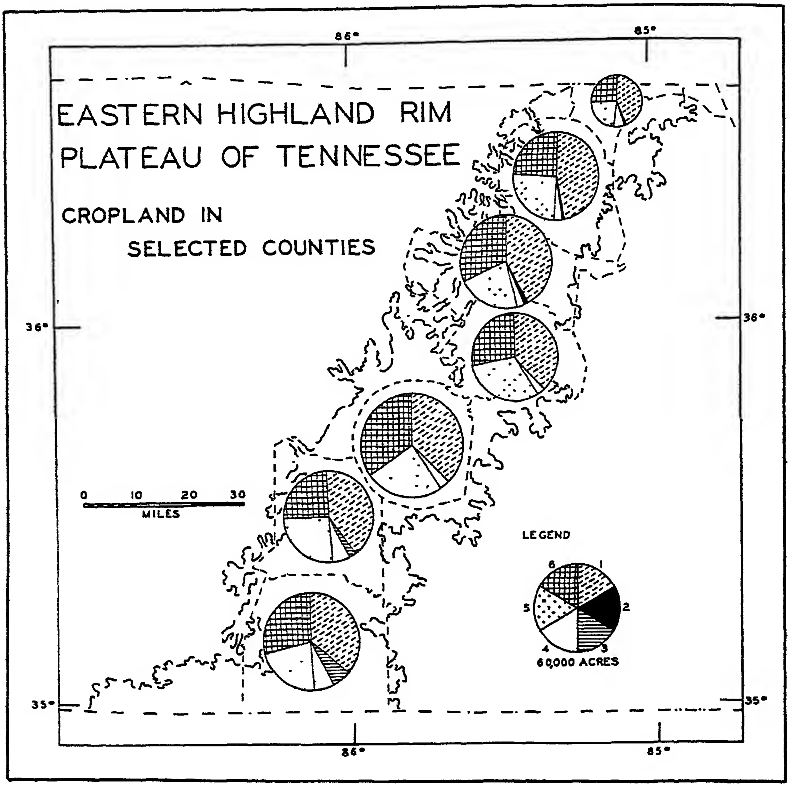


Fig. 5

KEY TO SYMBOLS

1. Corn	3. Cotton	5. Hay
2. Tobacco	4. Wheat	6. Other crops

of small anticlines and of greater stream erosion, owing to its nearness to the Cumberland River.

The major portion of the improved land is not in crops. This land, which is a striking feature of the region, where land is usually cleared only that it may be plowed, indicates the submarginal character of much of it, especially in as much as the region cannot be said to possess an extensive dairy or similar industry which would utilize pasture. A general picture of distribution may be gained from Figure 5. Corn is the most extensively grown crop and, with wheat,

the major important grain crop. Hay exceeds wheat in acreage, although in many parts of the region the yields are poor and not in proportion to the acreage devoted to it. Two commercial crops are raised. To the north there is tobacco; both burley and the one-sucker varieties are produced. In the southern part, where a longer growing season permits its production, cotton is raised. Usually more than a quarter of the cropland is devoted to a wide range of miscellaneous crops. These include the hardier grains, vegetables, and sorghum, which allow the farm to fit into the scheme of general self-sufficiency.

Type Studies

A clearer and more detailed picture of the distribution of land use may be gained from the following type studies, the exact locations of the areas of which are shown on Figure 4. Type study A (Fig. 6) is in the Barrens, and the soil is mainly infertile and light-colored. The Barren River is in the stage of youth, with steep

TYPE STUDY A

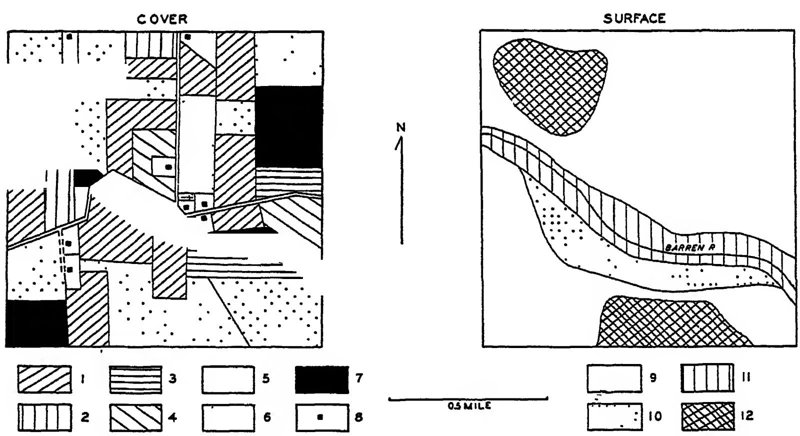


FIG. 6

KEY TO SYMBOLS

1. Corn
2. Small grains
3. Hay
4. Pasture
5. Sorghum
6. Abandoned land
7. Woodland
8. Farmstead
9. Upland
10. Diluvial terrace
11. Valley sides
12. Limestone residuals

TYPE STUDY B

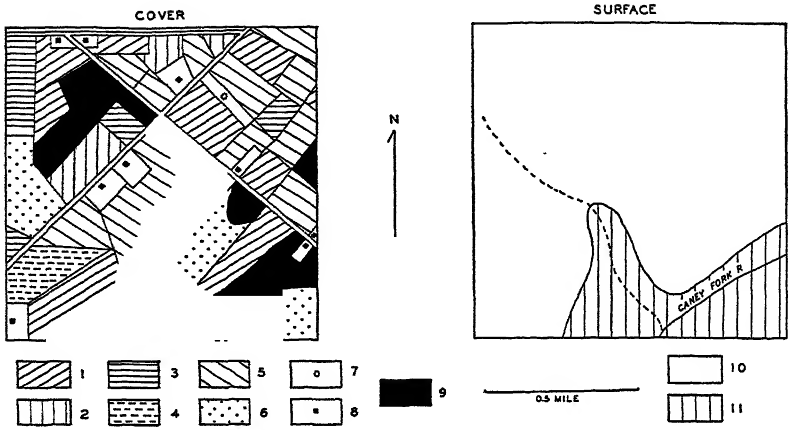


FIG. 7

KEY TO SYMBOLS

1. Corn	5. Pasture	9. Woodland
2. Small grains	6. Abandoned land	10. Upland
3. Hay	7. Orchard	11. Valley sides
4. Cotton	8. Farmstead	

valley sides, but in an earlier cycle developed a valley flat which today is an area of superior soil. Two limestone residuals rise above the usual level of the area. This entire section is in farms and, save for the wooded portions, would be designated by the census as improved land. In reality, much of it has been cleared and later abandoned. The principal crops are corn and small grains; corn and hay occupy the more fertile diluvial terrace. The limestone residuals are either left forested, as in the north, or, if cleared, as in the south, are later abandoned, for sheet erosion removes the top soils and robs them of what little fertility they originally possessed. Over the remainder of the area soil erosion is not a problem, and the abandoned fields are the result of soil depletion.

Type study B (Fig. 7) is located in the area of red soils underlain by upper Mississippian strata. The upland section is a gently rolling karst area. The valley sides are covered with forest or are devoted to pasture. Where cropping has been attempted it has usually resulted in abandoned fields, because of gullying. The fields

TYPE STUDY C

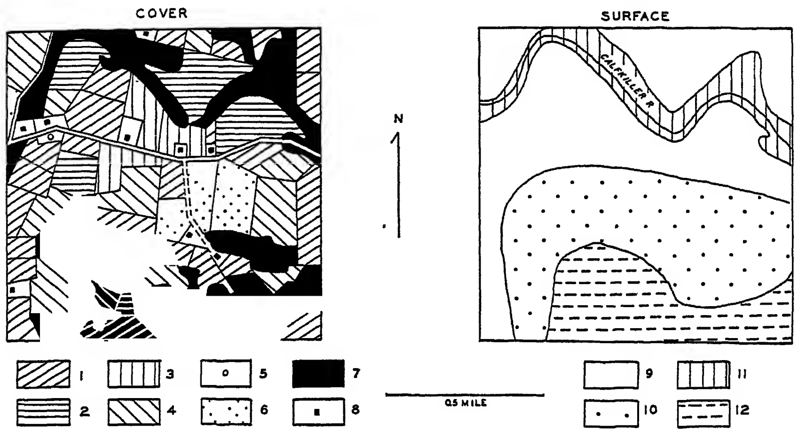


Fig. 8

KEY TO SYMBOLS

1. Corn
2. Hay
3. Small grains
4. Pasture
5. Orchard
6. Abandoned land
7. Woodland
8. Farmstead
9. Cove bottom
10. Ridge slope
11. Valley sides
12. Ridge top

are smaller and less regular than those in the Barrens, but the principal crops are of the same type: corn, small grains, and hay. The major problem here is erosion, which is especially prevalent near the streams or near the well-developed sinkholes (Pl. II, Fig. 2).

Type study C (Fig. 8) is in a cove of the Cumberland Plateau. Four divisions of surface may be recognized. To the south is the flat top of the Cumberland outlier; north of it, the slope to the cove bottom which is developed on upper Mississippian limestone and in turn is cut by the steep-sided valley of the Calfkiller River. The valley sides as well as the flat top of the Plateau are largely in forest, save for the small irregular clearings on the plateau. The cove bottom and the slope have been cleared. On this slope not even the coarser soils, a mixture of the sands of the weathered Pennsylvanian sandstone with the clay of the limestones, have kept the fields from erosion. This erosion has resulted, in many instances, in their abandonment. One suspects that much of the area at present in

TYPE STUDY D

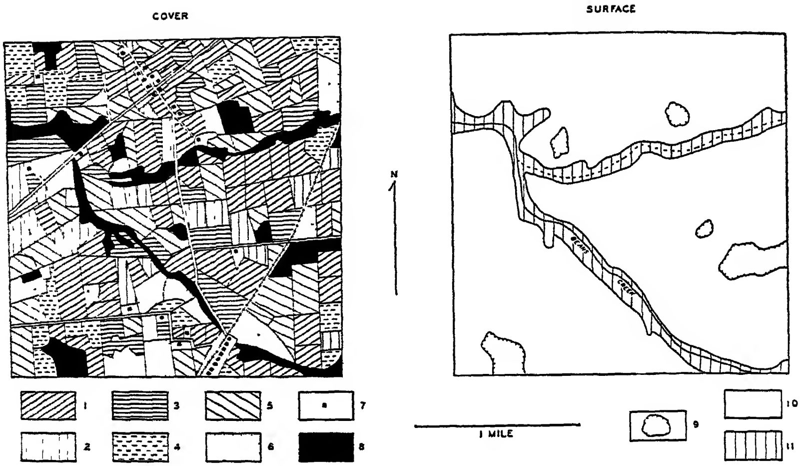


FIG. 9

KEY TO SYMBOLS

1. Corn	5. Pasture	9. Sinks
2. Small grain	6. Abandoned land	10. Upland
3. Hay	7. Farmstead	11. Valley sides
4. Cotton	8. Woodland	

use as pasture is in the process of abandonment, for it was formerly cultivated and has had much of its top soil removed. Crops here are similar to those in the two other type studies, and are most extensively grown on the cove bottom.

Type study D (Fig. 9) is another portion of the red-soil section, but it is farther to the south than that of type study B, and hence cotton is the dominant cash crop. The upland area is in relatively pure limestone, with well-developed sinks upon it. Much of the land along the streams and the sinkholes is in forest. Most of the abandoned fields are also near the sinks and are in each case the result of soil erosion. Cotton shares with corn and small grains the major portion of the land. A greater part of the pasture land is not permanent here, but is in rotation. This represents the portion of the Eastern Highland Rim Plateau which has the most prosperous appearance. Its general aspect and economy more nearly resemble those of the Central Basin than of the remainder of the Plateau.

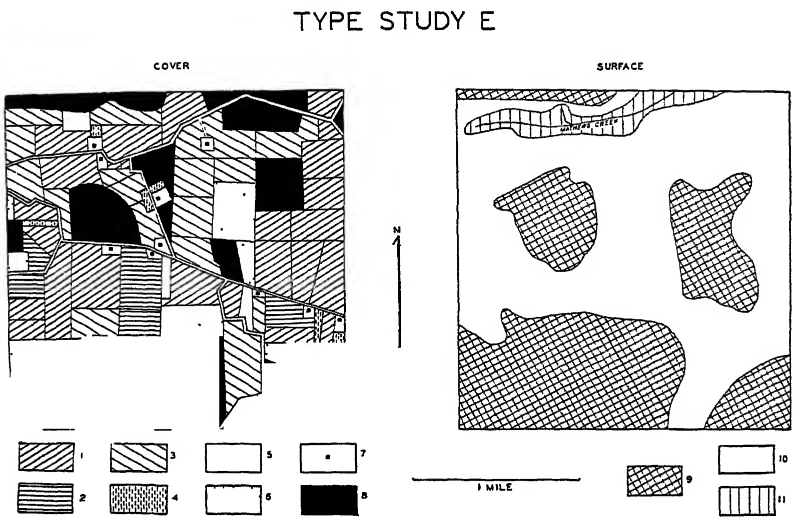


FIG. 10

KEY TO SYMBOLS

1. Corn	5. Sorghum	9. Limestone residuals
2. Hay	6. Abandoned land	10. Upland
3. Pasture	7. Farmstead	11. Valley sides
4. Tobacco	8. Woodland	

Type study E (Fig. 10) is located in the northern part of the region, where the area is much dissected by river action. Residuals of upper Mississippian limestone, covered with fertile but easily eroded red soil, rise above the general level of the upland, which is developed on lower Mississippian limestone and covered with a light-colored Barrens-type soil. Much of the surface of the residuals has been left in forest, and where it has been cleared for fields soil erosion has led to its abandonment. The principal crops are corn, small grains, and hay. Small patches of tobacco, usually of poor quality, provide the chief cash crop. This area is entirely unlike the commercial tobacco areas such as are found in the Kentucky Bluegrass. There are no tobacco barns, and the crop is usually dried in an empty portion of the stock barn or in an outlying shed. Most of the farming is of the self-sufficient type, and the farmsteads are poorly constructed and maintained.

To summarize, there is a general lack of harmony between the

agricultural pattern of the region and the underlying pattern of soil and surface. In the detailed studies what partial correspondence may be seen is apparently not so much the result of a conscious effort on the part of the inhabitant to adjust his use of the land to natural conditions as the result of attempting to clear and cultivate land unfit for crops, and later of being forced to abandon it because of either soil depletion in the Barrens or soil erosion in the remainder of the region. The explanation of this disharmony between the agricultural pattern and the underlying pattern of soil and surface is to be found largely in the settlement and development of the region.

SETTLEMENT

The Eastern Highland Rim Plateau was settled principally by middle-class farmers or yeomanry. These farmers, most of whom had originally been established in the Central Basin, doubtless moved from there mainly to escape the superior competition of the planter class during the early part of the nineteenth century.[6] But having achieved through this migration [7] freedom from planter competition, they were then faced with the problems inherent in their new location. Isolation resulted from the poor system of transportation, and low educational standards from the lack of any public-supported system of schools. Often unable to export what agricultural surplus could be produced, ignorant of better farming practices or of better economic opportunities which lay outside the region, possessing a high birth rate, as does the remainder of the South, the yeomen faced the problem of overpopulation in comparison with the productivity of the region. In consequence the land has been cleared, improved, and planted with little relation to its natural productiveness. Only where the slopes are steep or where the character of the soil is such that erosion or depletion has rendered them utterly unfit for cultivation have the fields been abandoned and allowed to return to forest.

[6] *Preliminary Population Report*, Sec. I A, maps 3 and 4. Nashville, Tenn.: Tenn. State Planning Comm., 1935.

[7] Straw, H. Thompson, "The Population Distribution and Change in the Eastern Highland Rim Plateau of Tennessee" (abstract), *Ann. Assn. Am. Geog.*, 30 (1940): 72–73.

PRESENT-DAY PROBLEMS AND SUGGESTED SOLUTIONS

Present-day problems in the region result from these general conditions. The problems are exemplified by the heavy relief loads, the nonpayment of emergency crop-loan money,[8] the great amount of state financial aid needed annually for schools, and the large proportion of farms with low incomes and of the self-sufficient type.[9]

The suggested solutions have fallen into two groups.[10] The first is to continue to improve the educational facilities, both schools and other educational services, such as the county farm bureaus and agricultural experiment stations, and the transportation, especially the farm-to-market roads. In this way it is hoped that emigration, which had an all-too-small development during the latter part of the second decade of the present century, will be continued and accelerated. It is also hoped that those who remain will learn better farm practices and by the improvement of roads be able to sell to urban markets outside the region a larger surplus of farm products, and thus raise the standard of living.

The second suggested solution is to develop nonfarm opportunities within the region, through either public or private initiative. The opportunity for mineral exploitation is limited. In the northern part of the region, in what is known as the Spurrier-Riverton oil field, there are a few scattered pools of petroleum caught in the anticlines. Small amounts of limestone and of clay are manufactured into cement (Pl. II, Fig. 3) and brick (Pl. III, Fig. 1) respectively. Even the geodes found in the Fort Payne chert are collected by the farmers in the area, washed, cracked open, and offered for sale to tourists (Pl. III, Fig. 2). None of these exploitations of minerals is extensive enough or gives promise of becoming so to indicate that it would answer the needs of the region for nonfarm occupations.

Forestry and associated industries seem more promising. The entire region was originally covered with a forest of hardwoods in which oak and hickory predominated.[11] The remnants of this early

[8] Lucas, Broder F., and Callahan, E. P., *Major Rural Land Use Problems in Tennessee*, p. 12. Nashville, Tenn.: Tenn. State Planning Board, 1936.

[9] *Ibid.*

[10] Bur. Agric. Ec., Bur. Home Ec., and For. Service, *Economic and Social Problems and Conditions of the Southern Appalachians*, U. S. Dept. Agric., Misc. Publ. No. 205, pp. 12, 132. Washington, D.C., 1936.

[11] Sterrett, W. D., "Marketing Woodlot Products in Tennessee." *Resources of Tennessee*, 7 (1917): 111–195.

forest are being exploited on a small scale today, and the towns of the region generally have mills using local timber (Pl. III, Fig. 3). Flooring, baseball bats, wagon spokes, and golf-club handles are some of the products made. The growing of timber should be expanded upon much of the area now devoted to agriculture. This is especially true of the northern section with its rugged terrain and the Barrens with their infertile soils. The portions of the red-soil area which are more level and hence less susceptible to erosion and especially much of the southern section, where the growth of cotton as a cash crop produces farm incomes above the average for the region, may well continue in agriculture. But most of the rest might be converted to farm-forest communities with an increase in the woodworking industries in the small towns of the region.

The best way to accomplish this change remains undetermined. Whether it should be by governmental action, which was unsuccessfully tried in one of the northern counties of the region,[12] or by private initiative, aided perhaps by rural zoning and a revision of the tax laws to fit the condition of forest land, remains undecided. Certainly it is true that, however accomplished, the development of the farm-forest communities would greatly improve living conditions.

If the ultimate solution to the problems of the region is found, whether by the improvement of education and transportation on the one hand or the development of nonfarm occupations on the other, it is safe to say that the present disharmony between the agricultural pattern and the basic pattern of soil and surface will tend to disappear. Whatever pattern of land use is developed in the future, it must bear a closer relation to this basic pattern in the region if the current human problems are to be avoided.

Western State Teachers College
Kalamazoo, Michigan

[12] Collins, W. E., and Matthews, M. T., *Local Rehabilitation for a Tennessee Rural County*, 20 pages (mimeographed). W. P. A. Coöp. Plan, Rural Res. Rep., 1936.

FIG. 1. View from the Central Basin, showing in the background the line of hills that marks the escarpment of the Eastern Highland Rim Plateau

FIG. 2. Duck River Falls, where the river passes over the escarpment of the Eastern Highland Rim Plateau. Most of the rock is Chattanooga shale, fragments of which can be seen in the lower right-hand corner

FIG. 3. The area underlain by Fort Payne chert. Once cleared for agriculture, it is now abandoned, save for occasional use for pasture. A scrubby stand of sassafras and oak is growing upon it

FIG. 1. The area underlain by St. Louis limestone. Owing to the karst development the relief is greater than that shown in Plate I, Figure 3. The line of hills in the distant background is the escarpment of the Cumberland Plateau

FIG. 2. A field in the red-soil area. It has been abandoned because of excessive gullying

FIG. 3. Cement plant near Cowan which uses local limestone for raw material

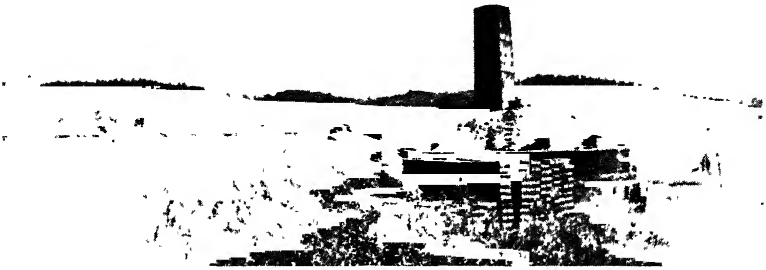


FIG. 1. Brick kiln near Algood which produces brick from local red clays. The kiln is in the red-soil area

FIG. 2. Geodes offered for sale to tourists on one of the main routes. They are found in the Fort Payne chert near the western part of the region

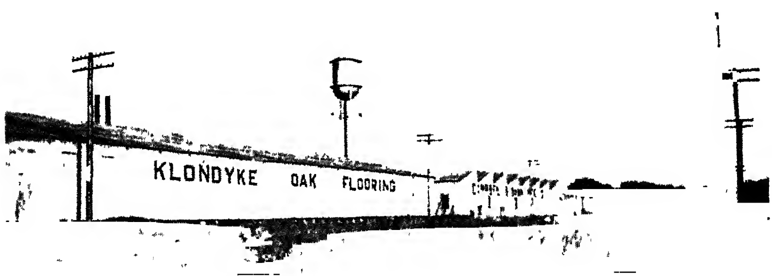


FIG. 3. Flooring mill at Tullahoma, typical of small woodworking factories in the region

GEOLOGY

JURASSIC AND CRETACEOUS STRATA OF THE CAMP DAVIS AREA, WYOMING

ERNEST DOBROVOLNY

CONTENTS

INTRODUCTION

Location

THE Camp Davis area comprises the lower part of the Hoback River drainage system west of Granite Creek in the southwestern part of the Teton National Forest, Wyoming. Camp Davis, located approximately in the center of the area and about 20 miles south of Jackson, is the Geology and Surveying Field Station of the University of Michigan.

Acknowledgments

The field work on which this report is based was done in August, 1938. The writer is indebted to the faculty of the Department of Geology of the University of Michigan for guidance in preparing the manuscript. Dr. R. W. Imlay checked all fossils and identified some and also assisted in measuring the section between Adams and Mumford creeks. Mr. Robert Hatch, of the Mineralogy Department,

examined seven thin sections of the sedimentary rocks, and his observations were particularly useful in making formational correlations.

Previous Investigations

There has been little previous investigation of the Mesozoic rocks of the Camp Davis area. In 1878 St. John and Clark (10, pp. 188–189), members of the Wind River Division of the Hayden Survey, completed a geologic and topographic map of an area lying between meridians 109° 30′ and 112° and parallels 43° and 43° 15′. During the course of the survey St. John measured a section eastward from the crest of the Wyoming Range to near the junction of Hunter Creek with Willow Creek. In Bulletin 543 of the United States Geological Survey Schultz (11, pp. 55–56) used the section measured by St. John, but added names for the purpose of correlation. This Bulletin contains a 100-foot–contour geologic and topographic map which includes the Camp Davis area. Since these early reconnaissance surveys several detailed sections in adjacent areas have been measured, and it now appears worth while to supplant the St. John–Schultz section near Camp Davis with a detailed one.

JURASSIC STRATA

Twin Creek Formation

In the Camp Davis area the Twin Creek formation is 725 feet thick and consists of dark-colored calcareous shales and thin- to thick-bedded limestones. The type section 100 miles to the south, near Twin Creek, Wyoming (12, p. 56), measures between 3,500 and 3,800 feet thick and differs from the Camp Davis section in containing a few light-colored sandstones and, apparently, no thick-bedded limestones. Thick-bedded limestones, however, have been reported by Bartram (1, p. 340) near the type locality and by Neely (6, p. 729) at Afton, 40 miles to the south. In the Camp Davis section the basal unit consists of 46 feet of gray limestone that weathers buff.

The Twin Creek formation of the Camp Davis area lies with apparent conformity on the Nugget sandstone, but the abrupt lithologic change from thick sandstone, supposedly in part of subaërial origin, to thick-bedded limestone suggests a break in sedimentation. Mansfield (4, p. 193) reports that in southeastern Idaho erosion occurred at the close of the deposition of the Nugget, and that the Nugget formation thins northward. These observations indicate

warping of the geosyncline at the end of Nugget time, though at most places little angular discordance has been noted between the Nugget sandstone and the overlying Twin Creek.

Mansfield (4, pp. 49, 98) also reports thicknesses for the Twin Creek formation in southwestern Wyoming comparable with that of the type section. According to sections measured mainly by Neely (6, pp. 715–770), the formation thins northward in Wyoming from 2,539 feet at Afton to 2,136 feet at Cokeville, 927 feet at South Piney Creek, and 730 feet at Camp Davis. Neely reports only 106 feet in the Lower Sundance (about 40 miles to the north and northeast in the Gros Ventre River section) and 397 feet in the Upper Sundance. The Lower Sundance of the Gros Ventre River Valley is referred in part to the Twin Creek and Ellis formations and the Upper Sundance to the Stump sandstone (6, pp. 737, 755).

The boundary between the Twin Creek and the overlying Upper Jurassic rocks in the Camp Davis area has not been definitely located because of the absence of any abrupt change in lithology and the lack of distinguishing fossils. It is arbitrarily placed 725 feet above the top of the Nugget sandstone directly above shales and thin-bedded limestones containing *Gryphea*, *Pentacrinus*, and *Camptonectes*. (See Figure 1 and the descriptions of the stratigraphic units which follow.)

The fossils obtained from Units 7, 8, and 9 of the Twin Creek formation of the Camp Davis area were identified by the writer and checked by R. W. Imlay. They are as follows:

Pentacrinus asteriscus (Meek and Hayden)
Gryphea calceola var. *nebrascensis* (Meek and Hayden)
Pholadomya sp.
Gervillea sp.
Camptonectes sp. (Meek)
Camptonectes bellistriatus (Meek)

These species are abundant in the Twin Creek formation of southern Wyoming and Idaho and in the Sundance formation of central Wyoming. In the Sundance of central Wyoming they are associated with ammonites, which are characteristic of early Upper Jurassic time (7; 2, p. 545).

A section on the ridge between Willow Creek and its tributary, Mumford Creek, measured from top to bottom, is described on page 433.

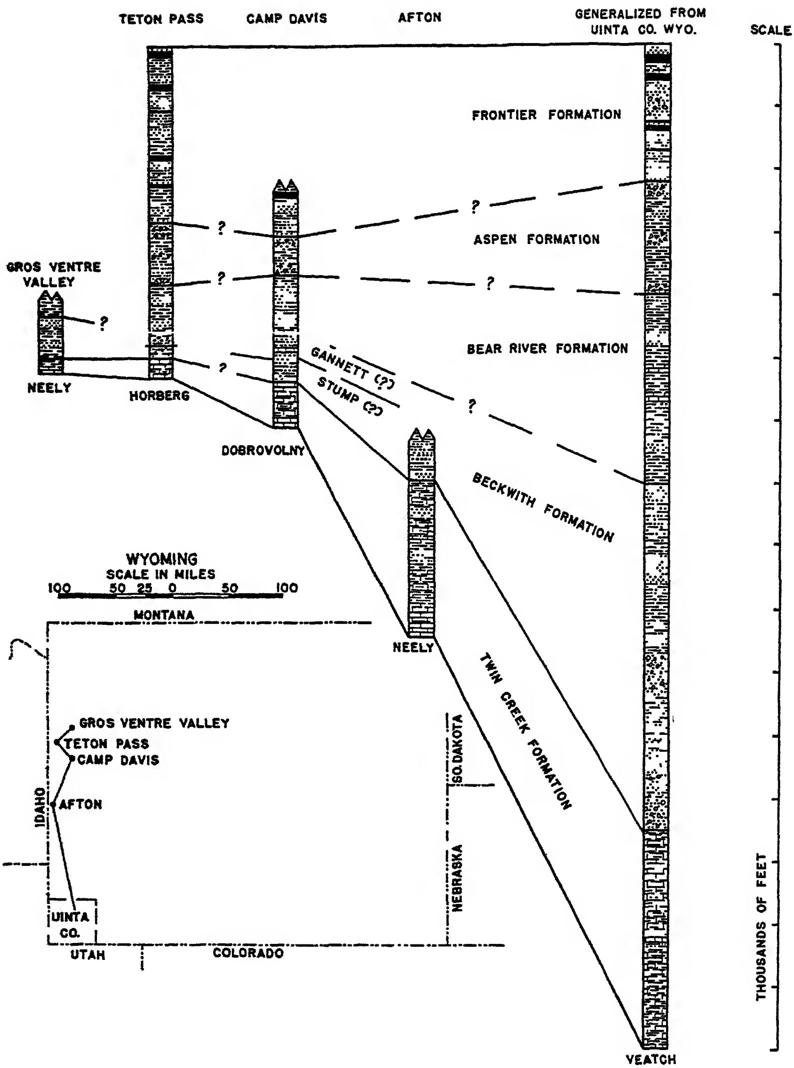


FIG. 1. Columnar correlation chart of Jurassic and Cretaceous strata of western Wyoming. The vertical position of the columns is entirely arbitrary, but chosen so as to illustrate postulated geosynclinal thickening

Units	*Thickness in feet*
9. Limestone and shale interbedded. Beds 2 to 10 inches thick. Limestone blue, weathering buff; shale black, weathering gray. Lower limestone beds mainly oölitic. Upper limestone massive, black and gray, oölitic, weathering blue, not cliff-forming. A *Gryphea* zone occurs 180 feet above base of unit. *Camptonectes* and *Ostrea* fragments occur below and above *Gryphea* zone. Other fossils are *Gryphea calceola* var. *nebrascensis* (Meek and Hayden), *Pentacrinus asteriscus* (Meek and Hayden), *Camptonectes sp.* (Meek), *Camptonectes bellistriatus* (Meek), *Pholadomya sp.*, *Gervillea sp.*	330 ±
8. Limestone, shaly, blue. White calcite and chalcedony veins parallel to bedding. Lower 7 feet very shaly. Distinguished from Unit 9 by cliff-forming character	65
7. Shale, calcareous, thin-bedded, blue, weathering red near top, makes distinct contact with limestone below	62
6. Limestone, massive, gray with some white mottling, contains dissolved parts of pelecypods (?), weathers brown. *Camptonectes* and *Ostrea* in lower part	8.5
5. Limestone and shale interbedded, gray, some members weather buff. Limestone becomes more shaly near top	125.5
4. Limestone, dense, coarser than beds below, steel-gray, weathers yellow-buff, oölitic	6
3. Limestone, fine-grained, steel-gray, weathers to blue, very narrow veinlets of calcite	11.5
2. Shale, weathers buff, some beds sandy	70
1. Limestone, gray, weathers to gray and buff, crystalline. H_2S to petroleum odor when freshly broken	46.5

Unconformity (?)

Nugget sandstone

Beckwith (?) Formation

Approximately 700 feet of beds in the Camp Davis area above the Twin Creek formation and below the Bear River formation are provisionally assigned to the Beckwith formation, which they somewhat resemble and whose stratigraphic position they occupy. The type locality of the Beckwith formation is in southwestern Wyoming (12, p. 57). The lower 440 feet, however, contain sandstones with fairly characteristic Stump lithology, and the upper 250 feet have characteristic Gannett limestones and shales. These formations are typically developed west of the Beckwith area in southeastern Idaho. The presence of maroon to red shales in both the Stump (?) sequence and the Gannett (?) sequence makes the separation into distinct

lithologic divisions a little uncertain. The lack of diagnostic fossils renders precise correlation impossible. It seems preferable, therefore, to use the more inclusive term "Beckwith formation" provisionally at the present time rather than to draw a line within it and recognize two formations.

The lowest member of the Beckwith formation in the Camp Davis area is a massive calcareous sandstone, 41 feet thick, containing *Pentacrinus* columnals. Its highest member is a maroon to lavender sandy shale. Its base is not marked by a conglomerate, as it is in the type section. A limestone bed about 450 feet above the base contains markings that may represent dissolved gastropods or pelecypods. This may be the fresh-water gastropod horizon referred by Horberg (3, p. 11) to the Gannett group of Teton Pass. (See correlation chart, Figure 1.) The Beckwith formation is overlain by the Bear River formation, which contains a fresh-water fauna that is considered to be of lower Upper Cretaceous age. Since the Gannett group is tentatively assigned to Lower Cretaceous age (4, pp. 101–103), the upper part of the Beckwith formation may likewise be Lower Cretaceous. No *Gryphea* zone was found high in the formation, such as that reported at Gros Ventre River and Circle Ranch (6, pp. 729, 737, 755).

The Upper Jurassic Preuss and Stump sandstones in the type section of southeastern Idaho are 790 feet thick, and the overlying Lower Cretaceous (?) Gannett group is 3,120 feet thick (4, pp. 101–103). These formations thin more rapidly to the north than they do to the northeast. For the Teton Pass area Horberg (3, p. 11) gives an average of 125 feet for the combined Preuss and Stump formations and 250 feet for the Gannett group. In the intervening Camp Davis area they are represented by 690 feet of the Beckwith. Neely (6, p. 755) does not mention the occurrence of Preuss sandstone on the Gros Ventre River, but records the Stump (Upper Sundance) as having a thickness of 575 feet.

The following units, which represent the Beckwith formation, were measured between Willow Creek and Mumford Creek, on the hill slope directly above the Twin Creek formation previously described.

Units	*Thickness in feet*
24. Shale, sandy, black, poor exposures, red to maroon in places	25
23. Limestone, fairly fine grained, blue on fresh surface, white on weathered surface, some light blue shale interbedded	50
22. Shale, red to maroon, with some nodular limestone	47
21. Limestone, fine-grained, fractured in lower part, where red shales appear intruded into the limestone, cliff-forming	47
20. Shale, maroon to dull red, some nodular limestone that looks brecciated; about 12 feet above base is a 4-foot gray to pink sandstone; near center is a 3-foot conglomerate of gray, brown, and black limestone pebbles one-half inch in diameter in a lime matrix	73
19. Limestone, thin-bedded, white to light blue, contains fracture septaria, outer part of veins of septaria is red chalcedony and inner part is calcite and quartz	14
18. Sandstone and shale, thin-bedded, cross-bedded, pink to gray	31
17. Sandstone, cross-bedded, fairly fine grained, some interbedded white sandstone	41
16. Shale, maroon to red, with some thin-bedded red to pink sandstone, shales in upper part a blue lavender	129
15. Sandstone, thin-bedded, cross-bedded, coarse-grained, color variable, with pink and gray dominant	10
14. Shale, maroon	38
13. Sandstone, calcareous, fine-grained, thin-bedded, gray to gray-green, contains *Pentacrinus*	51
12. Sandstone, thin-bedded, fine-grained, gray-green	14
11. Shale and sandstone, thin-bedded, fine-grained, light gray, weathers to a yellow gray	82
10. Sandstone, calcareous, massive, sandier in upper part than lower, buff, contains *Pentacrinus*	41

Several units above the red shale and siltstone of Unit 24 were observed by the Camp Davis students along the bed of the Hoback River, near its mouth. Below typical Bear River beds and above Unit 24 occur first some greenish gray shales, then some dark gray lithographic limestones, and below these a number of dark gray quartzitic sandstone beds. This indicates an unconformity at the base of the Bear River formation. It is probable that the sequence and the thickness of beds in the Gannett group also vary greatly within short distances.

CRETACEOUS STRATA

Boundary between Jurassic and Cretaceous Strata

Overlying the Jurassic Beckwith formation in the Camp Davis area are Cretaceous strata about 4,000 feet thick. No variation in attitude or distinct boundary between the systems was observed. To

facilitate mapping the top of the Jurassic (Beckwith formation) was arbitrarily placed at the top of the highest red sandy shale and the base of the Cretaceous (Bear River formation) at the bottom of the 12-foot bed of fine-grained buff to gray shaly sandstone which immediately overlies it. Lower Cretaceous rocks are probably not present, but might be included in the upper part of the Beckwith or the lower part of the Bear River formation. Any assumption of an unconformity between the systems must be based principally upon faunal differences, as suggested by Schultz (11, p. 54).

All the Cretaceous sections were measured on the west side of Willow Creek, about three quarters of a mile from its mouth, with the exception of Unit 1 of the Bear River formation, which was measured directly across the canyon on the east side.

Bear River Formation

Above the Beckwith formation in the Camp Davis area are beds 970 feet thick belonging to the Bear River formation, which consists of hard, brittle black shales, cross-bedded, buff to gray cliff-forming sandstones, and a few limestones, some of which are composed almost entirely of the shells of *Ostrea haydeni* and *Modiola pealei*. The formation at Camp Davis is quite similar to that in the type locality in southwestern Wyoming and differs only in containing thicker sandstones and less limestone. The fauna indicates that it is a fresh-water deposit. Conspicuous cross-bedding and lensing of the fairly coarse grained sandstones may indicate flood-plain origin.

A fauna characteristic of the Bear River formation of southwestern Wyoming (13, p. 28) was found in Unit 7 about 400 feet above the top of the Beckwith formation. Identified species are as follows:

Compeloma macrospira (Meek)
Corbula cf. *engelmanni* (Meek)
Charydrobia stockei (White)
Pachymelania cf. *chrysalis* (White)
Pachymelania cleburni (White)
Unio vetustus (Meek)
Ostrea haydeni (White)
Modiola pealei (White)

Most of the following section was measured about three quarters of a mile above the mouth of Willow Creek on the west limb of the Willow Creek anticline. Unit 1 was measured on the east side of Willow Creek, three quarters of a mile above its mouth.

Units	*Thickness in feet*
11. Shale, very sandy, dense, conchoidal fracture, blue-green; basal 4 feet not so sandy and weathers a light yellow buff	106
10. Sandstone, arkosic, medium-grained, gray to white, looks like fine-grained dark granite, weathers to slabs ½ to 3 inches thick. 6 feet	
Shale, very sandy, black to steel-blue, abundant plant remains, contains a gastropod, possibly Pyrgulifera. 4 feet	
Sandstone, arkosic, fine-grained, compact, dense, hard, gray-blue. 2 feet	
Sandstone, fine-grained, gray-green, some narrow black (micaceous ?) bands parallel to bedding, breaks up into platy slabs. 12 feet ...	24
9. Shale, sandy, nodular, black, nonfossiliferous, weathers platy. 15 feet	
Sandstone, arkosic, angular fracture, gray to green, parting surfaces stained red, brown, and yellow. 3 feet	
Shale, very sandy, dense, fractures angular to nodular, black, surface stained brown, some weathered surfaces carry plant remains; forms a small ridge. 10 feet	
Shale, weathers yellow-green at base, less yellow higher in unit, poorly exposed. 40 feet	68
8. Sandstone, arkosic, dense, finely laminated, grayish green, compact, weathers to slabs about one-half inch thick, cliff-forming. 6.5 feet	
Shale, black, indicated by slope. 9 feet	
Sandstone, dense, fine-grained, fine laminations, angular fracture, central and upper part denser, blue-green; cliff-forming. 39.5 feet	
Shale, black, partings contain evidence of plants; not well exposed. 48 feet	
Sandstone, arkosic, dense, angular fracture, grayish green; cliff-forming. 9.5 feet	
Shale, black, not well exposed. 17 feet	
Sandstone, arkosic, dense, grayish green, weathers to slabs about one-half inch thick; most prominent cliff former of the four sandstones in interval 8. 40 feet	169.5
7. Shale, blocky to nodular, brittle, black, stained red and yellow on fractured surfaces, breaks into square fragments; exposures poor. 150 feet	
Sandstone, very argillaceous, indicated by float. 5 feet	
Limestone, composed mainly of fossils, principally *Ostrea haydeni* and *Modiola pealei;* red on all surfaces, both fresh and weathered. 2 feet	
Sandstone, may be a very sandy shale, hard, dark color. 3 feet	
Shale, conchoidal to angular fracture, brittle, black, breaks into rectangular fragments, stained red and yellow in fractured surfaces. The following fossils were found in the lower or middle part of this shale member about 400 feet southeast of Ridge Flag: *Compeloma macrospira* (Meek); *Corbula* cf. *engelmanni* (Meek); *Charydrobia stockei* (White); *Pachymelania* cf. *chrysalis* (White); *Pachymelania cleburni* (White). 90 feet.	
Limestone, highly fossiliferous, gray to black, white to gray on weathered surface; found as float; contains *Pyrgulifera humerosa* and many poorly preserved gastropods. Same fossil bed found on top of ridge one-half mile south of Camp Davis contains: *Unio*	

Units	Thickness in feet
vetustus (Meek); *Ostrea haydeni* (White); and *Modiola pealei* (White). 5 feet	
Shale, weathers yellow, not definitely found in place. 5 feet	260
6. Sandstone, lighter in color and coarser-grained than sandstone below, cross-bedded, weathers into rounded blocks, not so prominent a cliff former as sandstone below. 28 feet	
Sandstone, arkosic, fine-grained, dense, light gray, breaks into columns. 34 feet	62
5. Shale, black, fractures conchoidal to angular and disklike, interbedded with 2 to 4 inches inclined or cross-bedded shaly sandstone; contains worm trails (?)	33
4. Sandstone, fine-grained, cross-bedded, white to gray, some black inclusions, buff on weathered surface; most prominent of the three cliff-forming sandstones in this part of Willow Creek, similar to sandstone below	24
3. Shale, nodular, soft, black, has shiny surfaces, feels like soapstone; contains worm trails (?); includes small sandy lenses	3.5
2. Sandstone, fine-grained, fragments angular, cross-bedded, white to gray, weathers to buff-yellow, contains seams of conchoidal black shale with worm trails (?). 12 feet	
Sandstone, fine-grained, blocky, lower part cross-bedded, white to gray, weathers to buff-yellow, cliff-forming. 18 feet	30
1. Shale, conchoidal to angular fracture, somewhat brittle, few secondary stains, some sandier beds form small cliffs. 160 feet	
Sandstone, fine-grained, compact near top, white, angular fracture, toward base more shaly and more nodular. 30 feet	190

Aspen Formation

In the Camp Davis area the Aspen formation consists of 590 feet of gray sandstone, a number of rhyolitic volcanic tuff beds, and some siltstone. It conformably overlies the Bear River formation, from which it may be distinguished by its tuff content. Megascopically the tuff beds resemble porcelain, but microscopically they consist mainly of fine unweathered dust fragments of volcanic glass. Some of the tuffaceous beds have color bands parallel to the bedding. Their conspicuous likeness to porcelain led Horberg (3, p. 11) to call them porcelainite. Rubey (in 9, pp. 2–3) reports vitric rhyolitic tuff from the Aspen formation in southwestern Wyoming and compares it with the tuff found in the Mowry shale of northeastern Wyoming. Since the Aspen at Camp Davis appears to contain considerably more tuff than the Mowry shale it may have been deposited nearer the volcanic source. Probably the gray sandstone, volcanic tuff, and siltstone are equivalent to the splintery and arenaceous shale of the type section in southwestern Wyoming (12, p. 67).

The lowest 8 feet of tuff is considered the boundary between the Aspen and the Bear River formations. For mapping purposes a 28-foot bed of tuff 54 feet higher in the section would be more suitable. The highest unit of the formation, as here determined, is 16 feet of tuff 575 feet above the base.

The following units represent the Aspen formation and were measured on the hill slope directly above the Bear River formation, previously described, about three quarters of a mile from the mouth of Willow Creek.

Units	*Thickness in feet*
21. Tuff, very fine grained to glassy, angular fracture, blue-black, white specks in places, light blue on weathered surfaces. A band near top weathers to a limonitic color. 16 feet Tuff, vitric rhyolite, angular fracture, spotted white and banded gray, matrix green. Some interbedded sandstone near center is cross-bedded and wedges out rapidly, but the tuff remains constant in thickness. 13 feet Tuff, very fine grained to glassy, dense, hard, brittle, angular fracture, gray-blue, no inclusions, clear. 6.5 feet Tuff, fine-grained to glassy, angular fracture, dense, white to light gray, somewhat spotted, weathered surface looks like a fine quartz sand cemented by silica. 3 feet	38.5
20. Arkose, pyroclastic, medium-grained, fragmental but cliff-forming, quartz, feldspars, chalcedony, and chert present, buff to brown. 5.5 feet Sandstone, arkosic, contains more reworked glass than sandstone above and not resistant, banded white with gray, yellow on weathered surface. 8 feet Tuff, very fine grained to glassy, angular fracture, blue to blue-gray. About 12 feet above base is a 6-inch banded sandstone. 21 feet . . .	34.5
19. Sandstone, arkosic, medium-grained, light gray, contains reworked tuff, quartz, and some biotite. Some plant fragments present. On weathered surface bands of blue tuff (?) alternate with white to gray bands; this is not so apparent on fresh surfaces. 2 feet Tuff, fine-grained to glassy, blue to black, small white specks scattered evenly throughout, red stains present locally. 5.5 feet Sandstone, arkosic, medium- to fine-grained, blue-gray, laminations have limonitic stain on weathered surfaces. 5 feet	12.5
18. Siltstone or shale, cherty or tuffaceous, gray to black, carbonaceous fragments visible. 42 feet Sandstone, medium- to fine-grained, brownish gray, makes small ridge. 1 foot	43
17. Siltstone, chalcedonic, tuffaceous, fine-grained, black to green. Upper part somewhat carbonaceous, but contains mainly reworked and layered tuffaceous material, generally black. Central part tuffaceous and chalcedonic, green. Lower part shaly, black to green,	

Units	*Thickness in feet*
angular fracture, breaks up into very small fragments, dotlike red stains	108
16. Sandstone, arkosic, evenly fine grained, cross-bedded, greenish gray, contains reworked chert, chalcedony, quartz, and orthoclase; includes white, gray, black, and yellow grains; prominent cliff former	17
15. Tuff, very fine grained to glassy, angular to conchoidal fracture, grayish green, small red stains on weathered surfaces, outcrops poor. Near center of unit a 1-foot green sandstone consisting of well-cemented reworked tuff, magnetite, and quartz (?), outer one-fourth inch weathered brownish	83
14. Tuff, very fine grained to glassy, angular fracture, gray to green. Lower part slightly banded white and light gray-blue. Upper part blue and unbanded	8
13. Sandstone, arkosic, fine-grained, slightly cross-bedded, buff to brown, most crystals white with some bronze and brown, reworked (?) tuff. 5.5 feet Siltstone, limonitic, fine-grained, *black*, small crystal faces reflect light, ganoid scales abundant. 2 feet Siltstone, very fine grained, conchoidal to angular fracture, green to blue, weak. 12.5 feet Tuff, welded, very fine grained, generally a light gray, small black dotlike inclusions, which may be magnetite, hard, resistant. 3 feet	23
12. Tuff, dense, very angular fracture, brittle, gray to black, banded, layers of gray bands 1 to 3 mm. thick alternate with layers of black 2 cm. thick; when broken and weathered looks like shale. 42 feet Tuff, dense, blue to gray; the lower 1 foot is banded, white alternating with blue; the upper part is green and contains disseminated red weathered inclusions about 2 mm. in diameter and 1 to 4 mm. apart. 4.5 feet Tuff, dense, fine-grained to glassy, angular fracture, gray-green, weak. 18 feet Tuff, dense, fine-grained to glassy, angular fracture, gray-green, slightly cliff-forming. 10.5 feet Tuff, dense, fine-grained to glassy, angular fracture, gray to green, weak, but stronger beds 4 to 8 feet thick alternate with 4- to 8-foot beds of weaker rocks. 61 feet Sandstone, arkosic, fine- to medium-grained, includes some reworked tuff, gray; brown-stained bands 1 mm. thick parallel to bedding on weathered surface. 7 feet Tuff, dense, fine-grained to glassy, angular fracture, gray to green, stronger beds 4 feet thick alternate with weaker beds of same thickness. 28 feet Sandstone, arkosic, fine- to medium-grained, gray, includes some reworked tuff, brown-stained bands 1 mm. thick parallel to bedding on weathered surface. 4 feet Siltstone or shale, very sandy, dense, conchoidal fracture, blue-green, outcrops poor. 42 feet Tuff, vitric rhyolite, dense, fine-grained to glassy, angular fracture,	

Units	*Thickness in feet*
shatters when struck with hammer, generally steel-blue; lower 0.5 to 1.0 foot banded, wavy blue and white, and set off sharply from upper unbanded 7.0 to 7.5 feet; banded part not definitely found in place, but not found above this position; contact of banded and unbanded part determined from float; unbanded part contains red specks 1 to 3 mm. in diameter spaced irregularly 1 to 10 cm. apart and in places entirely absent; interval may be 6 or 10 feet thick. 8 feet	225

Frontier Formation

Less than half the Frontier formation exposed at Camp Davis was measured. The measured part consists of gray to buff arkosic sandstones and buff siltstones. This formation conformably overlies the Aspen formation, from which it may be distinguished by the absence of volcanic tuff in distinct beds, although some of its silts contain reworked tuffaceous material. Several small coal seams occur about 500 feet above the last unit measured.

The following section was measured directly above the Aspen formation about one mile south of the mouth of Willow Creek.

Units	*Thickness in feet*
42. Sandstone, medium- to coarse-grained, more coarsely grained at base, slightly cross-bedded, contains reworked tuff or siltstone, quartz, feldspar, etc., brown to buff, upper part breaks into slabs ¼ to ½ inch thick and 4 or 5 inches square. The thickness may be greater than stated because last measurement was taken on top of the hill. 19 feet	
Conglomerate, coarse-grained, well-rounded pebbles of quartz, siltstone or tuff, and feldspar (?) ½ to 1½ inches in diameter. Pebbles are red, brown, white, and blue with brown cast general, grades into sandstone above. 0.5 foot	19.5
41. Siltstone, sandy, fine-grained, dense, conchoidal fracture, dull gray-brown, feels like soapstone, plant fragments indicated	16
40. Sandstone, very fine grained, cross-bedded, buff to yellow, the lower part is fine-grained and passes upward into a very fine sandstone; the top breaks into slabs ¼ to 2 inches thick	40.5
39a. Covered interval, may be part of sandstone above	6
39. Sandstone, conglomeratic to coarse-grained, largest pebbles about one-half inch in diameter consisting of brown cherty siltstone or tuff that is not very abundant, general pebble size ranges from 1 to 3 or 4 mm., buff to brown. The upper part is coarse-grained, textural changes gradational, weathers platy. Near the top a few cross-bedded lenses weather a light brick red	12
38. Covered interval, probably a siltstone	25

Units	*Thickness in feet*
37. Siltstone, fine-grained, dense, angular to conchoidal fracture, dull green; the upper 6 inches is a fine-grained green arkosic sandstone	5
36. Sandstone, arkosic, medium- to fine-grained, almost friable, greenish gray, not cliff-forming	12
35. Siltstone, fine-grained, angular to conchoidal fracture, dull green, a few irregular white veins; poor exposures	43
34. Sandstone, arkosic, chalcedonic or cherty, massive, gray to brown	11
33. Siltstone, fine-grained, dense, angular fracture, black; where exposed, beds 4 to 18 inches thick form steps; color variations secondary	117
32. Sandstone, arkosic, chalcedonic or cherty, medium-grained, massive, gray, somewhat cross-bedded, upper part weathers platy, cliff-forming	20
31. Siltstone, dense, angular fracture, generally greenish black to greenish gray, in places spotted white; 6 feet above base is a 1-foot bed of banded fine-grained tuffaceous sandstone; 28 feet above base is a dense, fine-grained, tuffaceous, and red-weathering sandstone about 8 feet thick; the rest of unit is a greenish gray siltstone	149
30. Sandstone, arkosic, fine-grained, cross-bedded, gray and brownish green. The lower 3.5 feet is lithologically identical with the upper 8.5 feet. At the center is a greenish black siltstone. The sandstone lenses into the siltstone	16
29. Siltstone, fine-grained, dense, angular fracture, blue-green, lower part weathers to black, upper part weathers to gray-green; not well exposed	67
28. Sandstone, medium- to fine-grained, most grains green, a few grains black, greenish gray, weathers white; lower part denser and stains a light pink; upper part banded and brown	3
27. Siltstone, very fine grained, angular fracture, green, red stains on exposed surfaces; in places small white veins one-half mm. or less in width form an irregular pattern	6
26. Sandstone, medium- to fine-grained, slightly cross-bedded, gray to white; light blue tuff 1 to 10 mm. thick is banded with light-colored sandstone; more tuffaceous near top	10
25. Siltstone, very fine grained, dense, angular fracture, gray-green to black; contact with sandstone above a wavy line the crest of which is 2 inches high and trough about 2 feet long	8
24. Sandstone, arkosic, medium- to fine-grained, cross-bedded near center, gray-green; some 1-mm. quartz (?) crystals; banded with light blue tuff 1 to 10 mm. thick; slightly speckled on weathered surfaces	8.5
23. Siltstone, angular fracture, fine-grained, blue-green to gray, a few brown and black inclusions on weathered surface	11.5
22. Sandstone, fine-grained, slightly cross-bedded, generally gray to white; reworked tuff, quartz, and biotite (?); white bands alternate with gray tuff 1 to 4 mm. thick	3

CONCLUSION

The Upper Jurassic strata of the Camp Davis area are intermediate in thickness between thicker equivalent strata in southwestern Wyoming and thinner equivalent strata in northwestern Wyoming. The Cretaceous strata do not thin so perceptibly to the north as the Jurassic. In the Aspen formation there are many beds of rhyolite tuff that are good horizon markers.

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NEW SPECIES OF FOSSILS FROM THE MIDDLE ORDOVICIAN OF MICHIGAN

RUSSELL C. HUSSEY

THE only exposures of Middle Ordovician rocks in the State of Michigan are found in the Upper Peninsula, and the principal outcrops occur within a belt about twenty miles wide extending in a general northeasterly direction past the towns of Escanaba and Rapid River. The most complete section of these rocks is that along the Escanaba River, near the village of Cornell, where the contact between the Black River and Trenton formations may be seen. Limestones, dolomites, and calcareous shales are common throughout the sections, and many well-preserved fossils may be found in them, especially in the shaly portions of the rocks. The exact stratigraphic relations of the Middle Ordovician formations of Michigan with rocks of the same general age in other parts of the country have not been determined.

Phylum MOLLUSCA

Class PELECYPODA

Genus WHITELLA Ulrich

Whitella eardleyi, sp. nov.

(Plate I, Figs. 4, 8)

Description. — Shell small, oblique, elongate. Anterior end extending only slightly in front of the beaks, curving very gradually into the ventral margin. Posterior end evenly, strongly rounded. Beaks strongly incurved. Umbones broad, prominent. The strong umbonal ridge, slightly rounded near the beaks, extends almost to the posterior extremity. Hinge line short, extending less than half the length of the shell. Surface markings, where preserved, consist of low, rather widely spaced ridges.

Horizon and locality. — Trenton. Common at several localities, especially along the Rapid River near the village of the same name.

Genus VANUXEMIA Billings

Vanuxemia calveri, sp. nov.

(Plate I, Figs. 11–13)

Description. — Shell moderately large, ventricose. Umbones prominent, blunt, concave on the inner sides. Beaks widely separated. Anterior end short, blunt, extending but a short distance in front of the beaks. Posterior end strongly rounded. Ventral margin broadly, evenly rounded. Anterior muscle scars small, well defined, excavated out of the anterior end of the hinge plate. Posterior scars large, faintly impressed.

Horizon and locality. — Trenton. Escanaba River, near Cornell, Michigan.

Genus CUNEAMYA Hall and Whitfield

Cuneamya childsi, sp. nov.

(Plate I, Fig. 15)

Description. — Shell large, elongate. Posterior end sharply rounded, anterior end truncate. Umbones broad, prominent. Posterior umbonal ridge strong, broadening posteriorly. Anterior umbonal ridge well developed, gradually widening as it extends to the ventral margin. Between the two ridges is a well-defined sulcus extending to the ventral edge, which is indented at the intersection. Strong, somewhat irregular concentric ridges cover the surface and are especially prominent just posterior to the sulcus. Traces of finer concentric lines are seen in a few places on the surface.

Horizon and locality. — Trenton. Groos Quarry, near Escanaba, Michigan.

Class GASTROPODA

Genus HOLOPEA Hall

Holopea weaveri, sp. nov.

(Plate I, Figs. 9–10)

Description. — Shell large, low-spired, volutions expanding rapidly. Tops of the whorl very slightly rounded, flattened in places, sloping sharply down to the suture, which is deeply impressed in the cast. Sides of the last whorl broadly convex. Umbilicus very small.

Horizon and locality. — Black River, near Trenary, Michigan.

Genus BUCANIA Hall

Bucania buckwalteri, sp. nov.

(Plate I, Figs. 5–7)

Description. — Shell moderately large, high. Slit band bordered on each side by a delicate ridge. On either side of the band the surface is covered by a sharply defined network, with the meshes arranged in rows running in two main directions; one row runs across the volutions somewhat obliquely forward; the other, at a strongly oblique angle backward and inward toward the slit.

Horizon and locality. — Trenton. Escanaba River, near Cornell, Michigan.

Genus LIOSPIRA Ulrich and Scofield

Liospira bachmanni, sp. nov.

(Plate I, Figs. 14, 16)

Description. — Shell large, low, three volutions preserved. Periphery of last volution sharply angular; less angular on the other whorls. The slope above the periphery toward the suture is flat or very slightly concave. A low ridge borders the deeply impressed suture. The shell below the periphery slopes strongly and evenly toward the umbilicus, which is moderately large.

Horizon and locality. — Trenton. Groos Quarry, near Escanaba, Michigan.

Phylum ARTHROPODA

Class CRUSTACEA

Subclass Trilobita

Genus AMPHILICHAS Raymond

Amphilichas staebleri, sp. nov.

(Plate I, Figs. 1–3)

Description. — Glabella very convex, with the middle lobe strongly elevated above the lateral ones. Posterior slope of the middle lobe straight, except for a slight concavity about one third of the distance down the slope. Curvature of the anterior slope of the middle lobe abruptly downward from about the mid-point. Slopes

of the lateral lobes from front to back moderately convex, steepest in front. Palpebral lobes low, separated from the lateral lobes by a furrow that is nearly parallel to the furrow separating the central from the lateral ones. Neck furrow well developed. Surface covered with pustules of various sizes, with the largest ones quite numerous and prominent.

The middle lobe of the glabella is lower with relation to the lateral lobes than in *Amphilichas Cucullus;* the anterior slope of the middle lobe is more abruptly rounded, and the curvature of the lateral lobes is less convex.

Horizon and locality. — Black River, near Trenary, Michigan.

University of Michigan

EXPLANATION OF PLATE I

1–3. *Amphilichas staebleri,* sp. nov.
- 1. Top view of glabella
- 2. Anterior view of glabella
- 3. Lateral view of glabella

4, 8. *Whitella eardleyi,* sp. nov.
- 4. Left valve
- 8. Anterior end

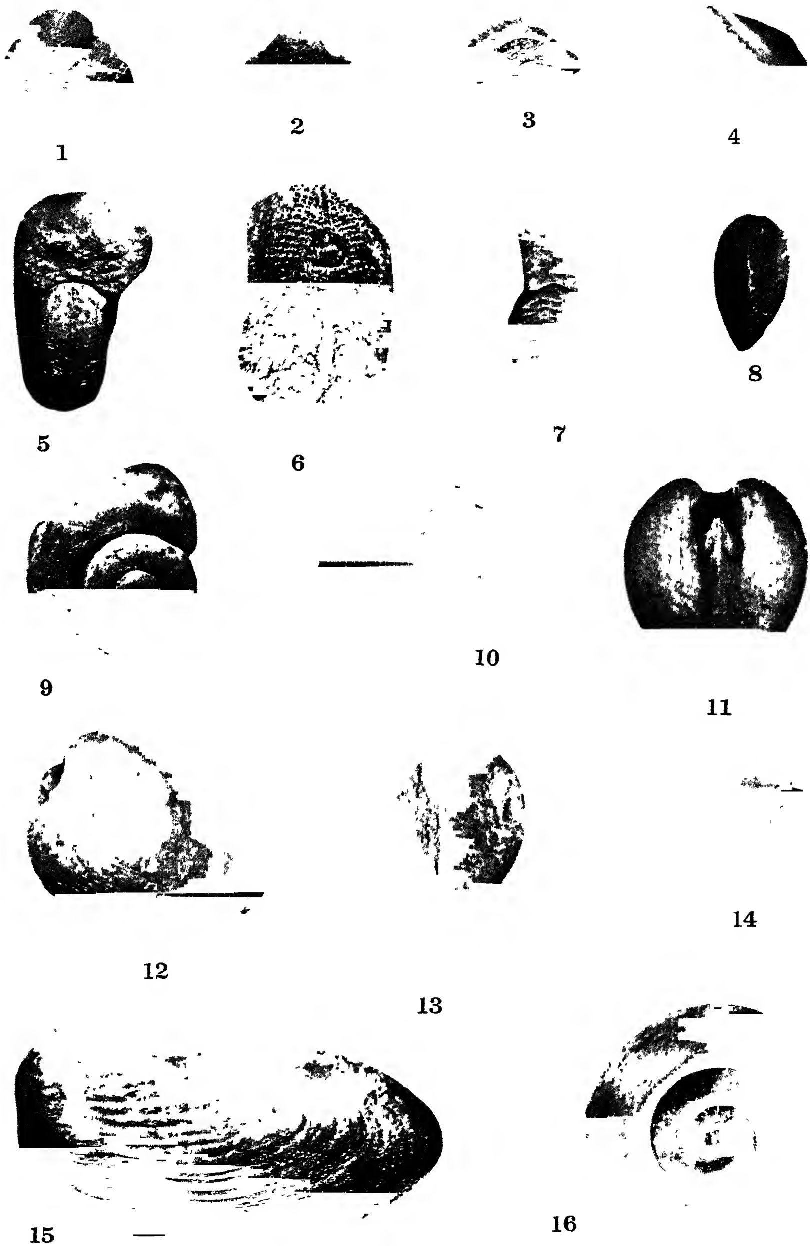
5–7. *Bucania buckwalteri,* sp. nov.
- 5. Apertural view
- 6. Surface enlarged two times to show markings
- 7. Lateral view

9–10. *Holopea weaveri,* sp. nov.
- 9. Apical view
- 10. Lateral view

11–13. *Vanuxemia calveri,* sp. nov.
- 11. Anterior end
- 12. Left valve
- 13. Hinge view

14, 16. *Liospira bachmanni,* sp. nov.
- 14. Lateral view
- 16. Apical view

15. *Cuneamya childsi,* sp. nov.
- 15. Left valve



Fossils from the Middle Ordovician of Michigan

ANTHROPOLOGY

A POSTULATED CORRIDOR OF FOLSOM MIGRATION

RAYMOND K. CASSELL

IMPORTANT new discoveries bearing on the question of the antiquity of man in America reveal evidences of a very early hunting people who lived along the eastern front of the Southern Rocky Mountains. Manifestations of this culture were first detected in the banks of a small intermittent tributary of the Cimmaron River some ten miles west of Folsom, New Mexico. Here was found a distinctive type of projectile point, now commonly called Folsom point, which was directly associated with the bones of a species of bison that lived in Pleistocene times.[1] The consensus of the specialists who coöperated at the site in 1928 supported the belief that man was present in the area at an earlier period than had formerly been supposed, and the date for the remains was tentatively placed at the close of the Pleistocene.[2] This opinion formed the basis for a revolution in archaeological thought, and from that time forward scientists, instead of unceremoniously rejecting claims of great antiquity for this early culture, began to look for further evidence.

Several years later excavations were begun in a locality about 300 miles north of Folsom, where many of these peculiar points had been found on the surface. Diggings here yielded a rich culture layer in which, besides bison bones and Folsom points, there was a definite complex of more than 2,000 associated stone implements.[3] The antiquity of this cultural aggregate was determined when the soil deposits upon which the occupation level rested were correlated with an established geological chronology. Drs. Bryan and Ray believe that the stratum which lies immediately beneath the cul-

[1] Roberts, F. H. H., Jr., "A Folsom Complex," *Smithsonian Miscellaneous Collections*, Vol. 94, No. 4. 1935.

[2] *Idem*, "The Folsom Problem in American Archaeology," *Early Man, a Symposium*, edited by G. G. MacCurdy, pp. 153–162. Philadelphia: Lippincott Co., 1937.

[3] *Ibid.*, p. 158.

ture layer belongs to a glacial substage, and they estimate that this substage existed throughout the Southern Rockies about 25,000 years ago.[4]

Although the Folsom site in New Mexico cannot be specifically correlated with the same geological deposit, it appears to be stratigraphically related to the Lindenmeier site near Fort Collins, Colorado; and because of the marked likeness of their situations, the similarity of the cultural objects, and their close relationship in time and space these sites may be regarded as two separate manifestations of the same culture.

This view implies the possibility that Folsom man had traversed the country between Folsom and Lindenmeier. Within historical times the distribution of man and his routes of movement have here been largely dictated by factors of the physical environment. It is logical, then, to suppose that the wanderings of Folsom man may also have been regulated by certain physical considerations. It appears necessary, therefore, to examine the factors which probably limited his movement, and to point out a route that he might have used when crossing the territory between Folsom, New Mexico, and Fort Collins, Colorado.

The general area between the sites coincides with the physiographic unit known as the Colorado Piedmont.[5] It is bounded on the east by the western escarpment of the Central Great Plains and on the west by the rugged foothills which constitute the transitional zone between the mountains and the plains. Broadly viewed, its surface forms are characterized by gently rolling plains, which are varied by buttes and tablelands (Fig. 1). The processes of denudation at work here have produced only minor topographic changes since the Pleistocene. Two perennial streams, the South Platte in the north and the Arkansas in the south, flow across the area from west to east. They have cut comparatively broad and shallow drainage basins, so that only a low divide separates them. The mesa country, in the midst of which Folsom is located, is the only feature of the terrain that presents a barrier to movement between these sites, but by making use of any one of several passes this country can be easily crossed.

[4] Bryan, Kirk, and Ray, Louis L., "Geological Antiquity of the Lindenmeier Site in Colorado," *Smithsonian Miscellaneous Collections*, Vol. 99, No. 2. 1940.

[5] Fenneman, Nevin M., *Physiography of the Western United States*, pp. 30–40. New York: McGraw-Hill Book Co., Inc., 1931.

Fig. 1. Landforms of the State of Colorado

This map is a section of a map of the landforms of the United States prepared by Erwin Raisz in 1939 to accompany W. W. Atwood's *Physiographic Provinces of North America*.

Today the climate of the Colorado Piedmont is semiarid. Precipitation is low and sporadic, the rate of evaporation is high, and the seasonal variations of temperature are extreme.[6] It is only when the rainfall is considerably above normal that natural sources of drinking water are fairly well distributed over the entire area. During the warmest months of years of normal rainfall most of these water sources dry up completely. In years of subnormal precipita-

[6] *The Forests of the Rocky Mountains,* United States Department of Agriculture, Forestry Division, Bull. No. 2, pp. 221–235.

tion drinking water is to be found only in the trunk streams and at the perennial springs scattered along the edge of the foothills. Characteristic dry-land types of vegetation, including a variety of short grasses and xerophytic shrubs, cover most of the region.

The climate which existed when glaciers occupied the mountain valleys must have been cooler and wetter than the climate of today. The presence of invertebrates in the Lindenmeier culture layer and the evidence of solifluction phenomena still preserved in the terrace gravel indicate that the temperatures were lower.[7] Presumably the precipitation required to nourish the glaciers in the mountain region was greater. But in the adjacent Piedmont the climate was probably even drier than it is at the present time, for the cold winds descending from the mountain ice field would be warmed and would become drying winds on the plains. Such moisture-absorbing winds would tend to produce true desert conditions in the Piedmont area.

In a region with this type of climate the cruising range for bison, the animal upon which Folsom man depended for food, would be closely related to the distribution of dependable supplies of drinking water. Doubtless there were years when the bison ranged over most of the area, but they were indeed exceptional.

During the greater portion of the time these animals were probably restricted to the narrow extent of territory paralleling the trunk streams and to the more favorable zone along the border of the foothills, where ground water emerges as either springs or spacious valley marshes. This border zone forms the axis of a corridor-like region that is limited on the east by the desert barrier and bounded on the west by the mountains. Since drinking water and excellent meadow grasses were to be found in this corridor it appears logical to assume that bison might always have been grazing there.

Men who relied on the bison for food probably learned rather readily that the best hunting grounds in the region were in this postulated corridor, and doubtless they made hunting excursions north and south throughout the extent of the mountain zone. Because they would find food and water in some part of this corridor at all times and because the terrain facilitates north and south movement, it must have been the pathway between the two sites where evidences of Folsom culture have been exhumed. The extension of this corridor northwest from Lindenmeier links it up with

[7] Bryan and Ray, *op. cit.*

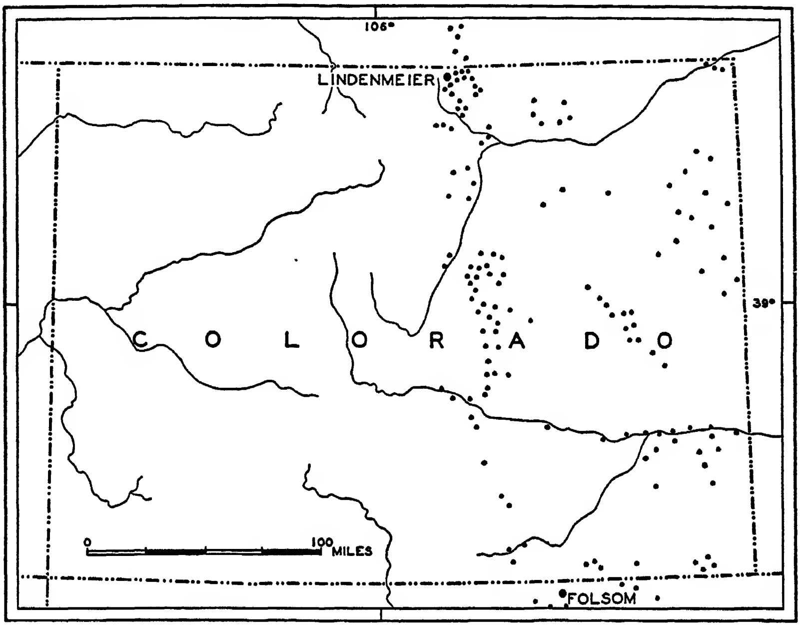


Fig. 2. Archaeological sites in the corridor between Folsom and Lindenmeier (after E. B. Renaud; see note 9)

the route over which aboriginal man is thought to have emigrated from Asia to central North America, that is, the way suggested by Johnston, which leads eastward through central Alaska to the Mackenzie River, and thence southward along the eastern front of the Rockies.[8]

An examination of the results of an archaeological survey of eastern Colorado shows that this corridor had been the temporary habitat and the avenue of movement for men antedating the modern American Indian, but of much less antiquity than that which is attributed to Folsom man (Fig. 2).

The distribution of these archaeological sites is closely associated with the sources of water supply. To judge by the bones and lithic

[8] Johnston, W. A., "Quaternary Geology of North America in Relation to the Migration of Man," pp. 9–45 of *The American Aborigines, Their Origin and Antiquity; a Collection of Papers by Ten Authors, Assembled and Edited by Diamond Jeanness.* Published for Presentation at the Fifth Pacific Science Congress, Canada, 1933. Toronto: The University of Toronto Press, 1933.

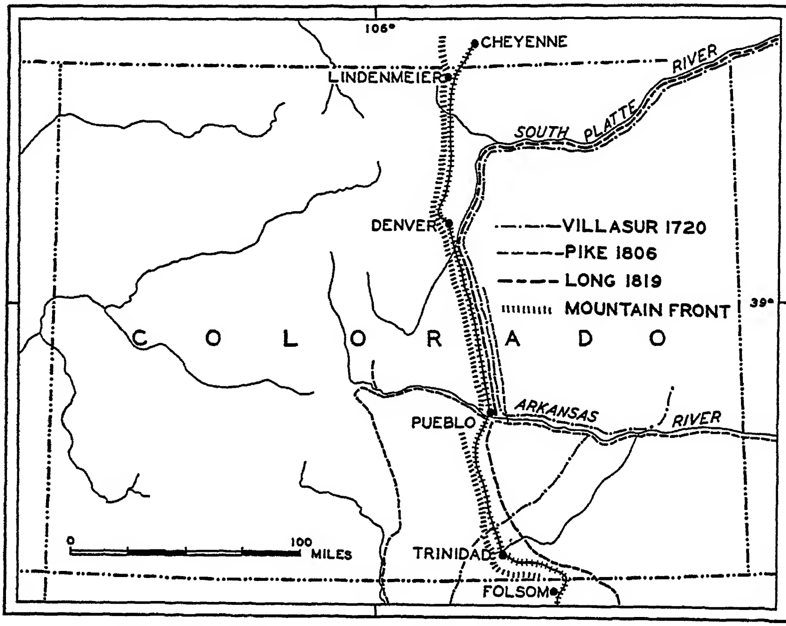


FIG. 3. First known routes through the Colorado Piedmont

implements collected here, in caves and rock shelters, it seems that a rather scanty population of nomads circulated through the better-watered areas in seasonal migrations, or in the more or less extensive local wanderings of their bands, in quest of food.[9]

It is interesting to note that historic man has also made use of the corridor (Fig. 3). The first recorded journey was that of Villasur, who in 1720 had been sent from Santa Fe by the Spaniards to reconnoiter the French in the Plains area.[10] In 1806 Zebulon Pike explored a part of the corridor, and in 1819 Major Long, another American, traveled through most of its extent. In 1826 the beginning of modern settlement in the Piedmont was marked by the establishment of a central fort and trading post on the Arkansas River, near present-day Pueblo. Almost immediately there followed the building of posts north and south along the foothill border extending from

[9] Renaud, E. B., *Archaeological Survey of Eastern Colorado*, No. 1. 1931. Denver: University of Denver, Department of Anthropology, 1931.

[10] Thomas, A. B., "Spanish Explorations into Colorado," *Colorado Magazine*, I: 289–294. 1924.

Folsom to Lindenmeier. Next came a number of stockmen, who pastured their herds along the foothill zone; and in the 1860's farmers began settlement in the basins of the South Platte and the Arkansas, and then spread north and south throughout the corridor.[11] By 1862 the United States Government had established a post road through the area, leading south from Denver to Santa Fe.[12] Finally, in 1876 the Denver & Rio Grande Railway constructed through the corridor a rather direct route which passes within easy access of both sites.[13]

CONCLUSION

In support of the view that this corridor has been the natural avenue of movement for the bearers of cultures from primitive to modern times we note that evidences of the Folsom culture have actually been found at watering places along the foothills. This was the zone where in the Late Pleistocene conditions for life of man and beast were presumably the most favorable. It follows, therefore, that this is the logical territory in which to carry on further explorations in the search for Folsom man himself.

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[11] Henderson, Junius, *Colorado*, University of Colorado Semicentennial Series, Vol. IV. 1927.

[12] Hafen, L. R., *The Overland Mail*, p. 237. Cleveland: A. B. Clark Company, 1926.

[13] Anderson, G. L., *A Decade of Colorado Road Building, 1870–1880*, Colorado College Publication, General Series, No. 209, pp. 66–72. 1936.

DISTRIBUTION OF PERFORATED HUMAN CRANIA IN THE WESTERN HEMISPHERE

WILBERT B. HINSDALE AND STEPHEN C. CAPPANNARI

WITHIN an area extending from Saginaw River, Michigan, to the western point of Lake Simcoe, Ontario, a distance of about 225 miles east and west, and from Thunder Bay, Michigan, to Windsor, Ontario, a distance of about 200 miles north and south, perforated crania have been found in sixteen locations, eight in Michigan and eight in Ontario.[1] Such crania have also been found in Ohio, in Mound 7 of the Hopewell group near Chillicothe, and in Mound 3 of the Turner group near Cincinnati.[2] In addition to drilled perforations, many of the crania discovered in Michigan since 1935 have large holes in the occipital region, formed by cutting out a circular section of skull plate.[3] A cranium with this feature was unearthed in Mound 7 of the Hopewell group near Chillicothe, Ohio.[4]

Circular disks removed from the occipital portion of crania by cutting are of two types, perforated and unperforated. Several of the latter type were exhumed at the Younge and the Rivière au Vase sites in Michigan, and another was secured by Wintemberg at the Lawson site, in Middlesex County, Ontario.[5] Specimens with per-

[1] Hinsdale, W. B., and Greenman, Emerson F., "Perforated Indian Crania in Michigan," *Occasional Contributions from the Museum of Anthropology of the University of Michigan*, No. 5, Ann Arbor, Michigan, 1936. Only seven sites for Michigan and seven for Ontario were mentioned in this paper. The eighth for Michigan is near Gibraltar, Wayne County; the eighth for Ontario is near Clearville, Kent County, where a circular portion of the top of a cranium, perforated around the edges with several holes, was excavated from a village site in 1939.

[2] *Ibid.*, pp. 10–11.

[3] Greenman, Emerson F., "The Younge Site, an Archaeological Record from Michigan," *Occasional Contributions from the Museum of Anthropology of the University of Michigan*, No. 6. Occipital holes are also found in crania from the Rivière au Vase site, near Mount Clemens, Michigan, a report upon which is in preparation.

[4] Shetrone, H. C., "Exploration of the Hopewell Group of Earthworks," *Ohio Archaeological and Historical Quarterly*, 35 (1926): 93.

[5] Wintemberg, W. J., *Lawson Prehistoric Village Site, Middlesex County,*

forations are reported for New York,[6] Ontario,[7] and Ohio.[8] In the descriptions of them the portion of the cranium from which the disks were taken is not given or else it is stated that the disks are from the parietal regions. Some of the perforated ones are notched or incised with simple patterns. A different kind of perforation is reported from a Woodland village site in Pennsylvania, at a point twenty-two miles up the Monongahela River from Pittsburgh. It was in a cranial fragment, five by three inches, in which had been cut an oblong hole an inch in length. This type of incision is quite characteristic of trephination, but the polish of the specimen suggests that it was used as a pendant.[9]

In all the skulls hitherto mentioned the perforation or cutting was made after death, but this operation is virtually the same as trephination, which is accomplished during the life of the individual. One example of trephination which the patient survived long enough for cicatrization of the bone to occur is known for Michigan.[10] Harlan I. Smith found trephined crania in the Fraser River valley on both sides of the international line — one in Washington and others in British Columbia. The greater number were skulls of females, young and old. Hrdlička, who examined these specimens, gives the opinion that the operations upon some had been made *intra-vitam.*[11] According to Jenness, the builders of the shell heaps practiced trephining.[12] The trephined crania are probably from the sites re-

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Ontario, Pl. XIII, 9. Canada, Department of Mines and Resources, Mines and Geology Branch, National Museum of Canada, Bulletin No. 94, Anthropological Series No. 25, 1939.

[6] Beauchamp, William M., *Horn and Bone Implements of the New York Indians,* Pl. 13. Bulletin 50, New York State Museum, 1902. Skinner, Alanson, *Notes on Iroquois Archaeology,* p. 128, Pl. 23. Museum of the American Indian, Heye Foundation, 1921.

[7] Wintemberg, *op. cit.,* Pl. XIII, 11.

[8] Shetrone, *op. cit.,* p. 38; Mills, William C., "Explorations of the Westenhaver Mound," *Ohio Archaeological and Historical Quarterly,* 26 (1917) : 257, Fig. 15.

[9] Engberg, R. M., "Algonkian Sites of Westmoreland and Fayette Counties, Pennsylvania," *Western Pennsylvania Historical Magazine,* 14 (1931) : 167.

[10] Hinsdale and Greenman, *op. cit.,* p. 1, Pl. I.

[11] Smith, Harlan I., "Trephined Aboriginal Skulls from British Columbia and Washington," *American Journal of Physical Anthropology,* 7 (1925) : 447–452.

[12] Jenness, Diamond, *The Indians of Canada,* p. 227. Canada, Department of Mines, National Museum of Canada, Bull. 65. Ottawa, 1932.

ferred to by Smith. What may have been a trephination was reported to Gillman from California,[13] but the description leaves doubt whether it was a trephination or a drilled perforation. Cosgrove reports a trephined cranium from a mound in Georgia, nine miles from Augusta. The skull was by itself, and incomplete.[14] Two more skulls exhaust the list of trephined crania from archaeological sites north of Mexico. They are reported by Shapiro from pre-Columbian sites in New Mexico — one at Mitten Rock, the other at Lamy. The former has a roughly circular opening, and it seems plausible that the operation was performed to relieve a pathological lesion of long standing. On the other the borders of the opening show cicatrization, but there was no evidence that the bones had been diseased.[15] Trephination was practiced in South America, and the literature of the subject is voluminous. According to Muniz, formerly surgeon general of the army of Peru, differently shaped openings, rectangular, circular, ovoid, and irregular, were made.[16]

The practice noted in this paper is not confined to the Western Hemisphere. There are numerous perforated and trephined skulls from prehistoric sites in Europe, and they have been found in more than twenty places in France alone. The traits represented by them may become more heterogeneous. Among the people of the Torres Straits the cutting of a hole in the posterior portion of the head was part of a process of mummification.[17]

In this paper the authors have intentionally avoided discussion. They merely give the distribution of the various types of skull perforation, in the hope it may afford a clue to the origin of this custom. True trephination, post-mortem trephination (the cutting of large holes in the occipital region), and post-mortem perforation by drilling have all occurred in the Lower Peninsula of Michigan. Though it is

[13] Gillman, Henry, "Certain Characteristics Pertaining to Ancient Man in Michigan," *Annual Report of the Smithsonian Institution for 1875*, p. 242.

[14] Cosgrove, C. B., "A Note on a Trephined Indian Skull from Georgia," *American Journal of Physical Anthropology*, 13 (1929): 353–354.

[15] Shapiro, H. L., "Primitive Surgery," *Journal of the American Museum of Natural History*, 27 (1927): 266–269.

[16] Muniz, Antonio Manuel, and McGee, W. J., "Primitive Trephining in Peru," *Annual Report of the Bureau of American Ethnology*, 16 (1897): 11–72.

[17] *Reports of the Cambridge Anthropological Expedition to Torres Straits*, I: 325. A. C. Haddon, Editor. London: Cambridge University Press, 1935.

not so far apparent that true trephination and the other two types have been found on culturally related sites, their occurrence in so restricted an area, when taken together with their fundamental similarity, suggests a relationship. Of the three types true trephination has the widest distribution. The others may be derivatives.

University of Michigan

NOTES ON THE ROACHED HEADDRESS OF ANIMAL HAIR AMONG THE NORTH AMERICAN INDIANS

VERNON KINIETZ

ONE of the few items of aboriginal Indian costumes described in sufficient detail by early writers to enable us to identify it today is the roached headdress of dyed animal hair. For the sake of brevity it is sometimes called simply a "roach." The most common material is the white hair from the tail of the deer. The brilliant red, the color invariably used in dyeing the hair, was undoubtedly largely responsible for its popularity with the Indians and also for the attention it attracted among the early writers.

The roach has been reported in use among the Indians from the early part of the sixteenth century to the present day. We do not have any records of the method of manufacture in the beginning of this span of time, but there is no detail of the process now in use that was not available in prehistoric times. After dyeing, the hair was woven into a long fringe on a bow frame such as that shown in Figure 1. The technique of weaving varied. Sometimes a double warp strand was used, and the doubled-over ends of the tufts of hair were placed between the strands and fastened after each tuft with two half hitches of the woof strand; sometimes there was only a single warp strand, as in Figure 2, over which the end of each tuft of hair was folded and lashed in place with a loop of the woof. Another, similar, fringe was woven of the longer turkey beards.

The roach or crest was formed by making a small circle of one end of the cord holding the hair. After the center was fashioned the next turn was run out six or eight inches and doubled back on itself, making a tail, as it were. The sides of this loop were then stitched together. Successive turns around the starting circle and the tail enlarged both. Each turn was stitched to the previous one. After two or three turns of the cord with deerhair fringe, the cord holding the turkey beards was used for at least two complete turns and some-

times a part of another around the starting circle. Then outside that there were a few more turns of deerhair fringe, and the headdress was complete. The finished headdress in Figure 1 of Plate I was made with moose hair in place of turkey beards. The bottom of this headdress is shown in Figure 2 of the same plate. The length of the headdress, measured at the bottom, varies from six to eight inches, according to the size of the wearer. The deerhairs are about three or four inches in length and the turkey beards six to eight.[1]

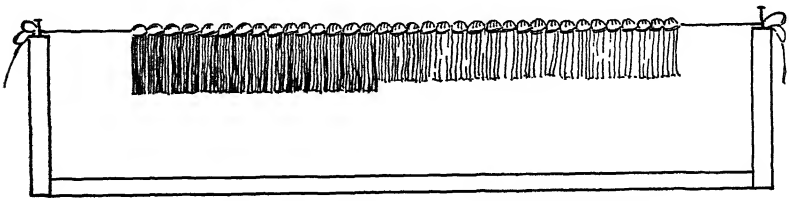

FIG. 1. The type of frame used in weaving the roach

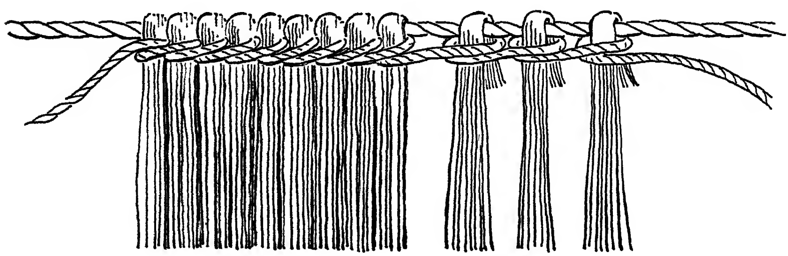

FIG. 2. Detail of weaving

In regions where the moose was common its hair seems to have been preferred to the combination of deertail hair and turkey beards, which were more frequently used because of the greater range of deer and turkeys. When moose hair was employed, it was all dyed red, but the turkey beards were left their natural black when combined with other materials. The dark tips of the moose hair did not take dye readily, and hence the roach showed on the fringe dark ends that made its appearance very similar to the deerhair roach. In recent years lack of these materials has led to the substitution of horsehair.

When not in use the headdress was protected from damage to the

[1] This description of construction is based principally on data collected among the Oklahoma Delaware in 1938. The trip was made possible by a grant from the Horace H. Rackham School of Graduate Studies.

hairs by inserting the end of a wooden stick in the hole left by the first turn, folding the hairs around it, and tying them. At present a strip of cloth is usually wound spirally around the folded roach, probably as a substitute for a skin wrapper.

In early days the headdress was fastened to the head by pulling a lock of hair from the top of the head through the hole in the circular part of the ornament and tying it. A short stick was often thrust through this lock of hair between the ornament and the knot. Occasionally a flat piece of bone was used as a spreader of the fringe. A single eagle feather was commonly thrust into the knot. This function of the knot has lately been taken over by a bone cylinder, attached to the spreader, into which the quill of the feather is inserted. The discontinuance of the long scalp lock has also made it necessary to attach the headdress to the head with leather thongs. A pair of thongs from the bone spreader passed through the hole in the headdress are brought down by the cheeks and tied under the chin. Another pair from the tail of the headdress are worn on either side of the neck and likewise tied under the chin. These thongs are discernible in the picture of the two Delaware in dance costume shown in Figure 1 of Plate II. Figure 2 is a front view of them. Inside the bone tubes the spreaders they wore had little wooden sticks, over which the cut end of the quill of the eagle feather was placed. This device allowed the feather to revolve freely, with no danger of its coming out.

According to all the evidence available, the roach was worn only on special occasions, such as feasts and dances, and by men going to war. With the black turkey beards projecting a few inches above the scarlet deerhair and with both ready to quiver at the slightest movement of wind or wearer, it was a very effective ornament. References show that the use of the roach in dances was almost as widespread as the roach itself. The type of dance differs among the various tribes, but the manner of wearing the headdress on such occasions is the same. Much of my information on the early nineteenth-century distribution of the roach is due to the desire of the Indians to array themselves in their showiest costumes while having their pictures painted. Among the well-known painters are Catlin, Lewis, King, and Stanley.

Cabeça de Vaca reported tassels of deerhair dyed red as one of the items from the interior brought in trade to the tribes on the Gulf

coast, presumably in Texas, about 1535.[2] They may have been roaches. In the same or the following year Jacques Cartier described the king at Hochelaga on the Saint Lawrence as wearing a headdress that was unmistakably a roach.[3] Its presence in the Penobscot River region in 1605,[4] New Netherlands in 1652,[5] among the Micmac,[6] Rapahanna,[7] and Powhatan[8] in 1607 indicates that the two references from the previous century were not to isolated instances of its manufacture. Other references with no tribal designation show that the distribution of the roach was rather general throughout the Atlantic coastal region at the beginning of white exploration.

Most of the foregoing references relate to Algonquian tribes, and when we find no similar mentions of the roach in the Southeast[9] it looks at first glance as if the roach were an ornament used exclusively by the tribes of Algonquian stock and the Iroquoian tribes they encircled, for, besides the Cartier citation, there is one by Sagard for the Huron in 1623.[10] The Cayuga pictured in the *Handbook of the American Indians*[11] is wearing one. As our knowledge of the West increases we find the distribution of the roach widening. For the Great Lakes region there are scattered references to the roach among the Winnebago,[12] Piankeshaw,[13] and Chippewa,[14] and very

[2] "The Narrative of Alvar Nuñez Cabeça de Vaca," edited by Frederick W. Hodge, in *Spanish Explorers in the Southern United States*, p. 56. New York: Charles Scribner's Sons, 1907.

[3] Lescarbot, Marc, *History of New France*, II: 119. Toronto: The Champlain Society, 1911.

[4] Rosier, James, "True Relation," *Coll. Mass. Hist. Soc.*, Ser. 3, 8: 146. 1843.

[5] van der Donck, Adriaen, "A Description of the New Netherlands," *Coll. New York Hist. Soc.*, Ser. 2, 1: 164. 1841.

[6] Lescarbot, *op. cit.*, III: 159–160. 1914.

[7] Percy, George, "Observations," in Edward Arber, *Travels and Works of Capt. John Smith*, I: lxv. Edinburgh: John Grant, 1910.

[8] Archer, Gabriel, "Discoveries of Capt. Newport," *Trans. and Coll. Am. Antiq. Soc.*, 4: 43. 1860.

[9] Timberlake reported stained deerhair as a head ornament among the Cherokee in 1765. *The Memoirs of Henry Timberlake*, edited by Samuel C. Williams, p. 75. Johnson City, Tenn.: Watauga Press, 1927.

[10] Sagard, Gabriel, *Long Journey to the Country of the Hurons*, edited by George M. Wrong, p. 155. Toronto: The Champlain Society, 1939.

[11] I: 223, *s.v.* "Cayuga." In *Bull. Bur. Am. Ethnol.*, 30. 1907.

[12] Radin, Paul, "The Winnebago," *Thirty-seventh Ann. Rep., Bur. Am. Ethnol.*, p. 109. 1923.

[13] Catlin, George, *North American Indians*, Vol. II, pl. 195. Edinburgh: John Grant, 1926.

[14] Densmore, Frances, "Chippewa Customs," *Bull. Bur. Am. Ethnol.*, 86: 37. 1929.

numerous ones for the Fox and Sauk.[15] The Delaware have already been mentioned. The Shawnee make and use the roach in the same manner as the Delaware.[16] In the Plains area it is well authenticated among the Iowa,[17] Oto,[18] Osage,[19] Kansas,[20] Pawnee,[21] Omaha,[22] Sioux,[23] Kiowa,[24] Arapaho,[25] Blackfoot, Gros Ventre, Assiniboine, Teton (Dakota), Ponca, and Arikara.[26] Among most of the Plains tribes the roach was connected with the hot dance and the Plains grass dance. Wissler was not able to give the distribution among the Plains-Cree, Plains-Ojibway, Shoshone, Cheyenne, and Flatheads, for whom he had only fragmentary data concerning the grass dance.[27] The roach is still made and used by many of these tribes, and a similar one of horsehair is worn by the Indians of the pueblo of Santa Ana in their buffalo dance. They say they received it recently from Oklahoma.[28]

With the exception of the Santa Ana pueblo, there is no evidence of the diffusion of the roach within historic times; in fact, the situation is quite the reverse, for if the tassels mentioned by Cabeça de Vaca were roaches this headdress was distributed throughout most of the United States east of the Rocky Mountains in earliest historic times. If Cabeça de Vaca was not referring to the roach one might conjecture that it was the invention of the tribes of the northeastern woodlands and that it moved westward from or with these tribes. However that may be, the object itself and the purposes for which it was worn have remained practically unchanged for over four hundred years.

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[15] McKenney, Thomas L., and Hall, James, *History of the Indian Tribes of North America*, Vol. II, pls. facing pp. 9, 65, 107, 167. Philadelphia: D. Rice and A. N. Hart, 1854. Catlin, *op. cit.*, pls. 280, 290, 291, 293, 295, 296.

[16] Information supplied by Erminie W. Voegelin and Mark R. Harrington.

[17] McKenney and Hall, *op. cit.*, Vol. III, pls. facing pp. 25, 173, 209, 233.

[18] *Ibid.*, pl. facing p. 214.

[19] Catlin, *op. cit.*, p. 48, pls. 150, 152, 154.

[20] *Ibid.*, pls. 132–135.

[21] *Ibid.*, pls. 138, 140.

[22] *Ibid.*, pl. 146.

[23] *Ibid.*, pl. 297.

[24] Grinnell, George B., *The Indians of Today*, pl. facing p. 60. Chicago: Herbert S. Stone & Co., 1900.

[25] *Ibid.*, pl. facing p. 16.

[26] Wissler, Clark, "General Discussion of Shamanistic and Dancing Societies," *Anthropol. Pap. Am. Mus. Nat. Hist.*, 11, Part 12:862–863. 1916.

[27] *Ibid.*

[28] For this information I am indebted to Leslie A. White.

PLATES I–II

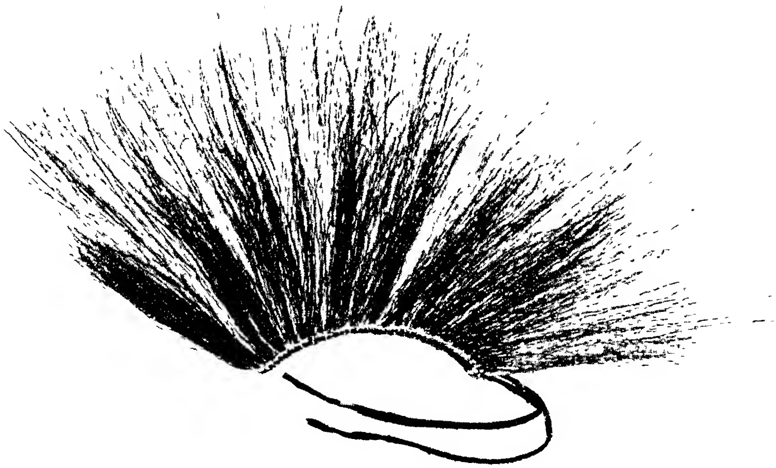

FIG. 1. Side view of small boy's roach of deer-tail hair and moose hair

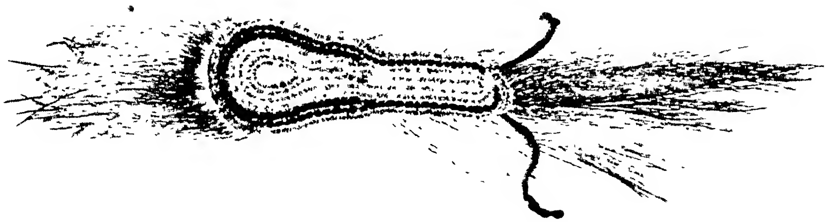

FIG. 2. Bottom view of the roach, showing the manner of construction. The white courses are of moose hair

Figs. 1–2. Side and front views of Delaware Indians, showing the manner of wearing the roach

POROSITY STUDIES OF ANCIENT POTTERY

FREDERICK R. MATSON

NO SET procedure or group of tests can be established for the technological study of ancient pottery because material from each site presents its own problems. The nature of the raw materials available, the degree of local ceramic development, and the specific technological problems formulated during the archaeological analysis of the pottery control the analytical techniques employed. It would be possible, by making many objective tests of every ware studied, to determine physical properties and compositional variations that might be of interest to some specialists, but they would be of little assistance in the cultural interpretation of pottery. Porosity determinations may belong in this category. During the past six years the porosity of some of the pottery studied at the Ceramic Repository at the University of Michigan has been measured in order to ascertain whether or not this test is useful in the objective description and differentiation of wares. Sufficient data have now been accumulated to permit an evaluation of the results.

Among the factors determining the porosity of a body are the type of clay used, the size and quantity of tempering material introduced, and the temperature to which the product is fired. An increase in the amount of aplastic added to a body will produce, within limits, a greater porosity (3, p. 410). The finer the size of the tempering material employed, the more porous will be the body (3, p. 412; 4, p. 274, fig. 4). Porosity is not affected at the lower temperatures by the degree of heat, but when clay is fired to the point where incipient vitrification is approached, the body begins to shrink and the amount of pore space decreases. When the body is completely vitrified, it has little or no porosity. Many clays have an apparent porosity of 15 to 40 per cent when fired to 1000° Centigrade (8, Chap. XVII, pp. 7–8). As Ries points out (10, p. 240), "Porosity has an important bearing on the strength of a fired clay body, its behavior as an absorbent, and its resistance to weathering, shock, abrasion, erosion, slagging, temperature strain, discoloring agents,

efflorescence, chemical attack by gases and liquids, and the destructive action of fungus growths."

"Apparent porosity" is an expression indicating the percentage of penetrable pore space in a body per unit of its bulk volume. It is determined by immersing the test pieces in water under specified conditions until they are saturated and then weighing them to determine the amount of liquid absorbed, the difference between the wet and dry weights being the amount of pore space that could be reached by the water. The bulk volume is determined either by measuring the amount of water or other liquid the saturated object displaces or by the loss of weight of the piece when it is suspended in water. The figure obtained when the pore space is divided by the bulk volume and the product is multiplied by 100, in order to express it in percentage, is termed the apparent porosity.

The procedure followed in securing the data used in this paper was that adopted by the American Ceramic Society (13, p. 456). Bulk volumes were determined by the loss-of-weight method. That loss of small particles from the fractured edges of the sherds while they were being boiled might not affect the measurements, the dry weight of the sherds was determined as the last step. This was particularly necessary when testing sherds from the eastern United States because, even after they had been thoroughly scrubbed, the friable edges of pieces tempered with shell or fine gravel tended to disintegrate. In a series of carefully cleaned sherds from Fort Ancient, Ohio, that were tested to determine the difference in dry weight before and after boiling, the loss in weight of 11 shell-tempered sherds averaged 2.63 per cent of the final weights, with a range of 1.33 to 4.47 per cent. In the 10 grit-tempered sherds the loss averaged 2.21 per cent, with a range of 1.11 to 4.74 per cent. This difference in weight is sufficient to necessitate the measurement of the dry weight after saturation. As Washburn has shown (12, p. 974), the boiling of low-fired clay bodies in water results in their partial rehydration, with an accompanying gain in dry weight. Since, however, the sherds were buried for long periods of time and thus were subjected to the action of ground waters, it seems likely that any partial rehydration that might occur would already have taken place before the pottery was tested. In studying some "Saharan" sherds from Egypt Myers and Earnshaw found that they lost weight after they had been soaked in water because of soluble salts that had been

present in them (7, p. 273). This suggests another advantage in the determination of the dry weight after saturation.

When one is considering porosity values, it would be of interest to know the limits of accuracy. Nine surface sherds from Tell Agrab, a site east of Baghdad excavated by the Oriental Institute of the University of Chicago, were tested four successive times. The individual results varied from 0.4 to 1.6 per cent, with an average variation of 0.9 per cent. In four of the sherds the porosity increased during the trials; in the other five it decreased. Apparently the removal of any soluble salts that might have been present in the sherds had little effect on the values. In reporting the apparent porosity of the "Saharan" sherds (7, p. 274) the mean of three determinations was given for each sherd. In no case was the probable error greater than 1.5 per cent. This agrees quite well with the Tell Agrab tests.

As a further check on the degree of reliability of the measurements the porosity values of sherds that fitted together were compared. When the figures for eight sets of sherds were studied, it was found that the difference between the members of a set ranges from 0.2 to 1.9 per cent, the average difference being 0.8 per cent. In another study the fragments of a large rock-tempered pot found near Clear Lake, Lapeer County, Michigan, were examined. Many of the sherds were badly disintegrated, but 25 in reasonably good condition were selected for testing. The average porosity of these sherds was 33.4 per cent, with a range in values of from 29.3 to 37.3 per cent, a range variation of 8.0 per cent. This pot, however, was an extreme case, for in a crude coarsely rock-tempered pot there may be marked textural variations. In general, it is reasonably safe to assume that the porosity variation between sherds of one vessel will be less than 2 per cent.

The results of the porosity studies of American Indian pottery are summarized in Table I.[1] In the statistical analysis of samples composed of fewer than 30 specimens the corrections given by Parmelee and Kraehenbuehl (9, p. 62, tab. 18) were employed.

The sherds from both Marksville and Coles Creek, Louisiana,

[1] Some of the measurements used in preparing Table I were taken in the Works Projects Administration's Archaeological Laboratory in Detroit, which is sponsored by the University of Michigan and supervised by Dr. Robert H. McDowell, through whose kind coöperation this work was made possible.

TABLE I

APPARENT POROSITY STUDIES — STATISTICAL ANALYSIS

All measurements are percentages.

Site	No. of specimens	Average	Range	Range variation	Standard deviation	Probable error	50 per cent of observations will lie between	Probable error of the mean	50 per cent of averages of like-size samples will lie between	Coefficient of correlation
Marksville, La.	28	30.6	24.0–38.5	14.5	3.2	2.2	28.4–32.8	0.4	30.2–31.0	10.4
Coles Creek, La.	29	26.2	21.5–31.3	9.8	2.3	1.5	24.7–27.7	0.3	25.9–26.5	8.7
Northwest Florida coast ... Sand-tempered	22	34.3	27.2–43.8	16.6	5.2	3.5	30.8–37.8	0.8	33.5–35.1	15.2
Ft. Ancient, Ohio Shell-tempered	22	33.2	29.6–38.6	9.0	2.6	1.8	31.4–35.0	0.4	32.8–33.6	7.8
Ft. Ancient, Ohio Rock-tempered	33	30.5	23.2–35.8	12.6	2.9	2.0	28.5–32.5	0.3	30.2–30.8	9.6
Younge Site, Michigan (5, p. 107) Rock-tempered	37	28.0	20.0–35.0	15.0	2.8	1.9	26.1–29.9	0.3	27.7–28.3	10.0
Hohokam Red-on-Buff, Arizona Mica-schist–tempered	28	30.9	25.0–36.9	11.9	2.8	1.9	29.0–32.8	0.4	30.5–31.3	9.2
Seleucia on the Tigris Figurines	42	31.6	24.4–37.7	13.3	3.5	2.3	29.3–33.9	0.5	31.1–32.1	10.9
Iraq sherds, unglazed	103	34.2	20.6–46.5	25.9	..	..	...	..	...	..
Seleucia, black glaze	17	34.0	27.3–37.8	10.5	..	..	...	..	...	..
Seleucia, red glaze	44	34.9	25.2–40.0	14.8	..	..	...	..	...	..
Karanis, Egypt Straw-tempered	9	33.0	29.2–39.0	9.8	..	..	...	..	...	..

are fine-grained and give no visual indication that one set is more porous than the other. This difference might possibly be significant in classifying sherds provided a sufficiently large series should be tested.

The sherds from the northwestern coast of Florida are tempered with very fine sand. The composition is reflected in the high porosity figure, which is due in part to the fineness of the aplastic. This series could be roughly divided into two groups. The porosity of half of the sherds tested was less than 35 per cent; these had at least the remnants of a slip on the surface and were red to brown. The value of the other sherds was above 35 per cent; they were white, soft, and weathered in appearance, and lacked any evidence of surface finishing. The large value of the standard deviation and the coefficient of correlation may indicate either that there are really two types or that the sampling is not representative.

The shell-tempered pottery from Fort Ancient, Ohio, is more porous than the rock-tempered ware. The difference between the averages, 3 per cent, is small, but it is significant because, although the range of the two groups overlaps, the one is distinctly higher than the other. The shell-tempered group shows less variability; this is indicated by the smaller range variation, standard deviation, and coefficient of correlation.

The rock-tempered Younge site pottery has a relatively low porosity, probably because of the coarseness of the aplastic used. The large range may be due in part to differences in the amount and size of the tempering material in the test pieces.

The mica-schist–tempered Hohokam Red-on-Buff sherds from near the present site of the Coolidge Dam in Arizona form a unit in terms of porosity range and average quite comparable with the pottery from the eastern United States.

The statistical analysis of these five groups of sherds would indicate that the porosity of wares such as those tested has a range variation of about 10 to 15 per cent, a standard deviation of 2.5 to 3, and a coefficient of correlation of 8 to 10 per cent.

In Table I appear also the porosities of sherds from Iraq and Egypt, to serve as a sampling from another part of the world. The figurines from Seleucia on the Tigris that were measured may be considered representative in their properties of the unglazed pottery from the site. They have been reported on in detail elsewhere (6).

This series, with its average value of 31.6 per cent, is very similar to the American Indian materials. At Seleucia imported sherds with red and black glazed surfaces were occasionally found. These glazed groups were much alike with respect to porosity, but the high average value, 34 per cent, is a little surprising. A detailed discussion of them is in preparation.

The average porosities of sherds from surface collections gathered at eight other sites in Iraq range from 30.7 to 36.2 per cent, and in several cases the range exceeds 20 per cent. This variability may be accounted for in part by the fact that there are textural differences among the sherds, some being more sandy than others. A few of the sherds had been fired to temperatures sufficiently high to produce lower porosities. Well-vitrified sherds not included in Table I had values as low as 4.7 per cent. The average value for the 103 Iraq sherds is similar to that of the Florida group, but the large range indicates that more than one physical type or firing temperature is included in the series.

The straw-tempered sherds from Karanis, Egypt, that were tested constitute too small a group to be considered definitive, but they indicate a relatively high porosity for this type of ware.

The published reports of porosity measurements summarized in Table II indicate, when considered with the preceding table, that there are regional and type porosity differences. The pottery from the southwestern United States tends to have a lower porosity than that from the eastern part of the country or from the Near East. At a site such as Fort Ancient or Pecos the tempering material used in the pottery may strongly affect the porosity. For the purpose of comparison the porosity range of some modern ceramic products is given in Table III. It will be seen that the porosity of ancient pottery is much greater than that allowable in present-day commercial wares.

It is difficult to correlate the porosity with other physical properties of pottery such as color, hardness, or thickness, since usually even a single ceramic type is far from homogeneous, owing to variations in the body composition and the firing temperature caused by that uncertain human element, the potter.

In order to determine the porosity of a ware it is necessary to test at least 20 sherds, preferably more, to establish the average and range. This information can then be used in a comparative manner, but as the results presented in the tables have shown, it is impossible

TABLE II

POROSITY STUDIES — PUBLISHED MATERIAL

All measurements are percentages.

Site	No. of specimens	Average	Range	Range variation	Reference
Armant Predynastic.......	5	..	36.9–68.6	31.7	(7, p. 276A)
"Saharan".......	5	..	33.9–41.6	7.7	(7, p. 276A)
Cameron Creek Village Mimbres pottery Early red paste...	..	28.11	23.9–30.6	6.7	(1, p. 34)
Early white paste..	..	30.03	22.0–39.0	17.0	(1, p. 36)
Coarse sandy paste	..	26.32	24.9–28.2	3.3	(1, p. 38)
Ashy gray paste...		27.6	24.4–32.2	7.8	(1, p. 38)
Pecos Black on white Blue-gray type *...	..	27.5	25.0–30.0	5.0	(11, p. 462)
Blue-gray type †...	..	31.2	27.2–34.6	7.4	(11, p. 464)
Crackle type......	.	24.1	16.8–31.9	15.1	(11, p. 466)
Biscuit ware "A" type †.......	..	36.6	31.8–40.4	8.6	(11, p. 488)
Glaze ware (6 types)..	..	23.6–26.2	18.4–31.6	13.2	(11, pp. 498–515)

* Untempered † Tuff-tempered

TABLE III

THE APPARENT POROSITY OF SOME MODERN CERAMIC PRODUCTS

(2, p. 314)

Product	*Percentage*
Common brick	
Surface clay	7–25
Shale	5–10
Drain tile	
Surface clay	7–15
Shale	5–9
Face brick..............	6–10
Paving brick............	3–5
Roofing tile	3–10
Sewer pipe	8
Wall tile	3–5
Floor tile...............	0.25–0.5
Hotel china	0.5–1.0

to obtain clear-cut divisions between most types in terms of porosity because of the overlapping of the ranges. Consequently, although porosity studies may give interesting information, they are not useful as objective criteria in ceramic classification or description, for after the values are established it is not always possible to test individual sherds and place them in their correct groups. It is conceivable that in detailed studies of pottery from one site porosity figures might be of importance in demonstrating the differences in firing temperatures. In general, however, since the porosity of most ancient wares, aside from the very high-fired ones like the Chinese porcelains and certain Mediterranean types, ranges approximately from 25 to 35 per cent for both the relatively crude American products and the finer ones of the Near East, it does not appear that porosity studies give sufficient usable information to justify the time taken in making them.

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CRANIA FROM THE PORTER MOUND, ROSS COUNTY, OHIO

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THE people who constructed the Porter mounds in Ross County belonged to that great Hopewellian cultural group whose center was in southern Ohio and whose remains have been traced from western New York to the river courses of Kansas, and from eastern Minnesota to Marksville, Louisiana. The domination of a considerable part of the region within these limits at the height of power of these people, as well as the extensive earthworks which mark the sites of their former occupancy, speaks for a relatively large population, but because of the customs of generally placing the burials on or near prepared floors, in mounds of compact, often acidic, clays, and of cremating a large number of their dead, the amount of skeletal material that has been preserved is negligible. The only Hopewellian series from Ohio that has been adequately described and for which a fair number of comparable measurements have been given is that from the Turner Group by Dr. E. A. Hooton,[1] and the only measurements available for pre-Hopewellian Woodland and Hopewellian crania from Illinois are those published in a preliminary report by myself.[2]

The Turner Group material consists of a primary series of thirteen males and ten females and a secondary one of eleven males and one female, or a total of twenty-four male and eleven female skulls; whereas the Illinois series contains thirteen male and ten female pre-Hopewellian Woodland skulls and about nine male and fifteen female skulls that can be assigned to the developed Hopewellian

[1] Hooton, E. A., "The Skeletal Remains," in *The Turner Group of Earthworks, Hamilton County, Ohio*, by Charles C. Willoughby, Papers of the Peabody Museum of American Archaeology and Ethnology, Harvard University, Vol. VIII, No. 3, pp. 99–132. Cambridge, Mass., 1922.

[2] Neumann, Georg, "Preliminary Notes on the Crania from Fulton County, Illinois," in *Rediscovering Illinois*, by Fay-Cooper Cole and Thorne Deuel, pp. 227–264. Chicago: University of Chicago Press, 1937.

phase because they were associated with types 2, 2*a*, 3, 3*a*, and 4 pottery and with typical Hopewell artifacts. This paucity of information on the racial relationships of a group as important in the cultural development of the aboriginal inhabitants of the Mississippi Valley as the Hopewellian people makes it necessary to describe all available material, no matter how fragmentary, so that by gradual accretion of data light may be shed on their racial history. This is particularly important because it has been shown that the Hopewellian culture antedated in Ohio [3] the Fort Ancient aspect of the Upper Mississippi phase and in Illinois [4] the Monk's Mound aspect of the Middle Mississippi phase.

Of the five mounds on the Tighlman Porter farm near the village of Frankfort, two, Nos. 15 and 38, were excavated under the direction of Mr. Warren K. Moorehead during August, 1888, and April, 1889, respectively, and described in 1889 [5] and 1892.[6] These mounds were the larger one of the two north of the Chillicothe and Washington pike and the southernmost of the three connected ones a few yards south of the pike. That they can be assigned to the Hopewellian phase, as was mentioned above, has been established with certainty, for they yield a wealth of artifacts and exhibit diagnostic structural features. The cultural traits characterizing the complex at this site are: dome-shaped burial mounds, prepared floor, stone pavement surrounding base, location in river bottoms, construction at one time; altars of fired clay, ceremonial hearths, deposits of ashes; copper celts, copper ear spools, copper breastplates; curved-base platform pipes, sheets of cut mica; dippers of marine shells (*Pyrula*), spherical shell beads, small disk-shaped shell (*Unio*) gorgets with two perforations, pearl beads; oblong bone gorget with two perforations; perforated bear, panther, and wolf canines; fabrics; flint knives and spearheads, polished stone celts; potsherds as accidental inclusions, a cache of pots; burials in flesh: extended, 22, flexed, 1; cremations, 13; partial burials, 2.

[3] Griffin, James B., *The Fort Ancient Aspect, Its Cultural and Chronological Position in Mississippi Valley Archaeology.* Ann Arbor, Mich., University of Michigan Press. (*In press.*)

[4] Cole and Deuel, *op. cit.*, pp. 199–206.

[5] Moorehead, Warren K., "Exploration of the Porter Mound, Frankfort, Ross County, Ohio," *The Journal of the Cincinnati Society of Natural History*, 12 (1): 27–30. Cincinnati: Published by the Society, 1889.

[6] *Idem, Primitive Man in Ohio*, pp. 113–131, 133–143. New York: G. P. Putnam's Sons, 1892.

Remains of thirty-eight individuals were found: sixteen in mound No. 15 and twenty-two in No. 38. Of the remains from No. 15 the bones of eight individuals are recorded either as not having been saved, in an advanced state of decomposition, or consisting of fragmentary remains from cremations; from mound No. 38 nineteen individuals are so described. This leaves at the most eleven persons whose bones might have been saved. Actually the remains of eight are represented in the collections of the United States National Museum.[7] This and the fact that Mr. Moorehead in both of his publications referred to mound No. 15 as "the Porter Mound" lead one to the conclusion that the material from the Porter mound in this collection came from mound No. 15 alone. None of the bones bear original numbers or letters. Among this skeletal material are four adult crania or parts thereof that merit description:

USNM 350,562. — Cranium, female, breakage slight; age: according to suture closure, 35–41, and according to attrition of teeth, about 35; light in weight and differing from the other skulls in texture; possibly one of the intrusive burials, but Hopewellian like the rest.

USNM 350,563. — Calvaria without the left temporal bone, female, adult, heavy in weight.

USNM 350,564. — Calvaria plus maxillae and mandible, male, some breakage; age: according to suture closure, 41–51, and according to attrition of teeth, around 50; heavy in weight.

USNM 350,565. — Calva plus maxillae and left zygomatic bone, female; age, judging from attrition of teeth, about 40; sutures sprung; of medium weight.

None of the four skulls exhibit artificial deformation. The sex characteristics are well marked; muscularity is uniformly small in the three females and about medium in the male. Morphologically the skulls are of the same type and can without hesitation be assigned to the Sylvid race, in accordance with von Eickstedt's terminology[8] but without including the Indians of the Plains in the Sylvid group. This corresponds to the eastern dolichocephals of earlier writers and to Hrdlička's "Algonkin" type, a term not used here because of its linguistic connotations.

The skull of the male is ovoid, with medium-sized divided brow ridges and a small glabellar region. The forehead is of medium

[7] In this place I should like to express my gratitude to Mr. Frank Setzler and to Dr. Aleš Hrdlička, both of the United States National Museum, for the privilege of describing a number of series of prehistoric crania from Ohio.

[8] von Eickstedt, E., *Rassenkunde und Rassengeschichte der Menschheit.* Stuttgart, 1934.

height and slightly sloped; it exhibits submedium postorbital constriction, small eminences, and a small amount of cresting, and is, as a whole, narrow. There are no traces of metopism. The parietals also exhibit a slight amount of cresting, are flattened off a little laterally, have only small eminences, and show pronounced lambdoidal flattening. A postcoronal depression and parietal foramina are lacking. The medium degree of muscularity is reflected in the medium supramastoid crest, a medium pharyngeal tubercle, small genial tubercles, and medium pterygoid attachments; the development of the mylohyoid ridge, however, is pronounced. The mastoid, also, is of medium size. There is no indication of an occipital torus, and, as is usual with most American Indians, the external occipital protuberance is lacking. In conformity with the long vault the temporal region shows only submedium fullness and a small sphenoid depression; the pterion region, which is of medium length on both sides, is in K on the right side and in H on the left. The curve of the occipital is pronounced; the bone is set low on the vault and is somewhat bun-shaped, as is typical of a great many Sylvids. On an average, the coronal suture is simple in serration, the sagittal submedium, and the lambdoid very pronounced, with ten Wormian bones. The base of the skull is not flat, the projected basion-porion distance being great, the condyle elevation large, and the basion elevation and petrous depression medium. The styloid processes are smaller than is usual in Sylvids. A pharyngeal fossa and pterygobasal foramina are lacking, the lacerate foramina small, the glenoid fossae of medium depth, the postglenoid processes small, the tympanic plates thin, the auditory meati oval, the external pterygoid plates medium, the internal ones small.

The oblong orbits with their small inclination are again typical, just as are the rest of the facial features. Thus the slight suborbital fossae, the zygomatic bones with large lateral but only medium anterior projection, the small nasion depression, the high, medium-wide nasal root, and the lack of prognathism (total, slight; midfacial, absent; alveolar, between slight and medium) form a complex that is rather diagnostic. On the right side both the facial and orbital portions of an infraorbital suture are present. The zygomatic process of the temporal is of medium robusticity, the nasal sills being not especially sharp, the nasal spine small, and subnasal fossa or sulcus lacking. The palate is high and paraboloid, the direction of the

transverse palatine suture is transverse, and the postnasal spine is medium in development. There is no palatine torus. The mandible is large, wide, heavy, and has a broad ramus — all individual variations that are reflected in the measurements. The bilateral chin is negative when the mandible is in a natural position, that is, fitted to the skull in the ear–eye plane. Mandibular alveolar prognathism as well as the eversion of the gonial angles is slight. The teeth exhibit an edge-to-edge bite, but it is hard to say whether that was the original condition, as there is fourth-degree attrition. The molar cusp patterns probably were 4–4–2 for the upper molars and 5–5–4 for the lower ones.

As was pointed out above, the three female skulls as a whole resemble the male skull closely in most morphological attributes if due allowance is made for the sexual factor. They differ from the male skull in that there is only a trace of supraorbital ridge development, that two have the median type of brow ridges, that one shows traces of metopism, that two exhibit medium postorbital constriction, that the frontal eminences in all three show medium development, that the median crest on the frontal is absent in two, that the sagittal elevation is lacking in all three, that two have medium-developed parietal bosses, that the ridges for the insertions of muscles are smaller, that the mastoid processes of two are small, that two show less lambdoid flattening, that the serration of the lambdoid suture is only medium, that the orbits are square in the complete skull, that both lateral and anterior projection of the zygomatic bones is slighter in two, that the zygomatic processes of the temporals are less robust (submedium), that the nasion depression is absent in two, that the mandible is small, and that there is no gonial eversion. In the one skull in which the face is well preserved the nasals are slightly concavo-convex, the nasal bridge is of medium height and width, and the incisors are slightly shovel-shaped. The cusp pattern for the upper molars of two individuals is 4–3–3 and 4–4–(?), and for the lower molars of one individual, 5–(?)–4.

Table I gives the measurements and Table II the indices for the female crania. The routine measurements[9] were taken on all four

[9] These measurements are: capacity (C), the cranial module (CM), mean thickness of left parietal (TP), glabello-opisthocranion length (L), maximum width (B), minimum frontal width (B′), basion–bregma height (H′), auricular height, porion to apex (PAH), nasion–basion length (LB); horizontal circumference over glabella (GU), nasion–opisthion arc (S), transverse arc over apex (AQ), and over bregma

TABLE I

MEASUREMENTS IN MILLIMETERS OF FEMALE CRANIA

Measurements *	USNM 350,562	USNM 350,563	USNM 350,565
C	...	...	...
CM	...	...	...
TP	5	5	4
L	175	179	(173) †
B	140	136	(131) †
B′	93	85	...
H′	...	...	...
PAH	116	...	...
LB	...	...	...
GU	503	505	...
S	356	...	...
AQ	320	...	...
BQ	313	...	...
GH	111	...	...
G′H	70	...	...
J	129	...	...
GB	100	...	...
IOW	99	91	...
SIOW	19	15	...
BOW	100	...	...
EOW	20	...	...
NH′	50	...	...
NB	29	...	...
DC	21	...	...
DS	11	...	...
SC	10	...	...
SS	4	...	...
LOBM	42	...	...
LOH	35	...	...
LOBD	39	...	...
ML	54	...	53
MB	67	...	69
GL	...	...	...
GL′	...	...	...
P ∠	86	...	...
NP ∠	89	...	...
AP ∠	79	...	...
G ∠	119	...	...
KL	100	...	...
KB	121	...	...
KH	30	...	...
WB	92	...	...
AB	33	...	...

* For explanation of measurements see note 9. † Approximately.

TABLE II

INDICES OF FEMALE CRANIA

Indices *	USNM 350,562	USNM 350,563	USNM 350,565
100 B/L	80.00	75.98	(75.72) †
100 H′/L	....	....	....
100 H′/B	....	....	....
100 H′/(L + B/2)	....	....	....
100 PAH/L	66.29	....	....
100 B′/B	66.43	62.50	....
100 GH/J	86.05	....	....
100 G′H/J	54.26	....	....
100 G′H/GB	70.00	....	....
100 J/B	92.14	....	....
100 B′/J	72.09	....	....
100 SIOW/IOW	19.19	16.59	....
100 EOW/BOW	20.20	....	....
100 NB/NH′	57.37	....	....
100 DS/DC	51.90	....	....
100 SS/SC	37.88	....	....
100 LOH/LOBM	82.58	....	....
100 LOH/LOBD	88.27	....	....
100 MB/ML	124.07	....	130.19
100 WB/B′	98.92	....	....
100 WB/J	71.32	....	....
100 KL/KB	82.64	....	....

* For explanation of indices see note 9.
† Approximate figure.

(BQ); nasion–gnathion height (GH), upper facial height (nasion–alveolar point) (G′H), bizygomatic width (J), midfacial breadth (GB), internal orbital width (frontomalare orbitale) (IOW), subtense to an arc over nasion from the preceding two points (SIOW), biorbital breadth (BOW), anterior interorbital breadth (maxillofrontale) (EOW); nasal height (NH′), nasal breadth (NB), dacryal chord (DC), subtense to dacryal arc (DS), simotic chord (SC), simotic subtense (SS); orbital breadth from maxillofrontale (left) (LOBM), orbital height (left) (LOH), orbital breadth from dacryon (left) (LOBD); maxilloalveolar length (ML), maxilloalveolar breadth (MB), facial length: basion–alveolar point (GL) and basion–prosthion (GL′); total facial angle (P∠), midfacial angle (NP∠), alveolar angle (AP∠), left gonial angle (G∠); condylosymphysial length (KL), bicondylar width (KB), height of symphysis (KH), biangular width (WB), and minimum breadth of ascending ramus (AB). The indices in Tables II and III are self-explanatory.

TABLE III

COMPARISON OF THE PORTER MOUND MALE CALVARIA WITH RELATED SERIES

Measurements are in millimeters.

Measurements and indices *	USNM 350,564	Turner, series No. 1		Early Woodland		Anderson Village		Maples Mills	
C	1,370	...		...		...		...	
CM	156	154 8 †		153.6 †		152.8 †		153.9 †	
TP	7	5	(12)‡	5	(12)	5	(26)	5	(24)
L	187	183.15	(13)	183 3	(12)	181 8	(26)	182.5	(23)
B	139	138.50	(12)	138.5	(11)	136.3	(26)	137.4	(23)
B′	96	92	(13)	94.3	(12)	94.0	(29)	93.4	(24)
H′	142	142.66	(3)	138.9	(7)	140.4	(22)	141.7	(21)
PAH	119	...		118.3	(9)	...		...	
LB	112	105.3	(3)	102.7	(7)	104.5	(22)	104.2	(21)
GU	525	516 §	(12)	...		...		...	
S	371	381 ‖	(6)	...		...		...	
AQ	323	...		...		...		...	
BQ	320	318	(8)	...		...		...	
J	(131)¶	137	(1)	140.3	(9)	140.2	(26)	136.5	(24)
IOW	99	...		...		...		...	
SIOW	21	...		...		...		...	
NB	26	27.1	(5)	26.7	(9)	26.9	(26)	26.1	(23)
KH	34	37.6	(7)	...		...		...	
WB	107	101.0	(4)	101.4	(7)	104.4	(23)	103.6	(21)
AB	39	36.4	(11)	...		...		...	
100 B/L	74.33	75.58	(12)	75.76	(11)	75.16	(26)	75.39	(23)
100 H′/L	75 94	77.72	(4)	76.55	(7)	76 91	(21)	77.76	(21)
100 H′/B	102.16	99.65	(2)	100.78	(7)	103.46	(21)	103.12	(21)
100 H′/(L+B/2)	87.12	88.82 †		86.34 †		88.05 †		88.75 †	
100 PAH/L	63 64	...		...		...		...	
100 B′/B	69.06	67.77	(9)	68.57	(10)	68.80	(26)	67.97	(23)
100 J/B	(94.24)	98.56	(1)	101.75	(8)	102.85	(25)	99.01	(23)
100 B′/J	(73.28)	69.34	(1)	67.19	(9)	67.03	(26)	68.69	(23)
100 SIOW/IOW	21.31	...		...		...		...	
100 WB/B′	111.46	109.78 †		107.53 †		110.64 †		110.92 †	
100 WB/J	(81.68)	73.72 †		72.14 †		74.29 †		75.91 †	

* For explanation of measurements and indices see note 9.
† Calculated from the means in this table.
‡ Numbers in parentheses following the means indicate number of individuals.
§ May be about 10 mm. less if taken over ophryon.
‖ According to Hooton too high "and probably due to the circumstance that the only skulls of the short series upon which this measurement could be taken happened to be the largest skulls of the series."
¶ Parentheses in this column indicate that figures are approximate.

skulls, but because of the fragmentary nature of the male skull this list was cut down considerably for that individual; his measurements are given in the first column of figures in Table III. As the measurements of males, only, for three of the series that I wish to use are available at present, the comparison is made on this basis, and is,

therefore, limited to the measurements that could be taken on the male skull from the Porter mound. In other words, the purpose of the paper is to compare the measurements of this skull with those of a number of related series rather than to demonstrate the close relationship of these series to each other, a comparison that will form the subject of a later paper.

The capacity of the skull although perhaps a little lower than the means of other Sylvid groups definitely falls within the normal range of these eastern Indians, and, if the comparison in size is made on the basis of the cranial module, compares favorably with them. The skull is heavy, and thicker than the average skull, and has a fairly robust mandible. It is long, narrow, and rather high, with a moderately wide frontal and an extremely long base. The bizygomatic width is small if the estimate made on the broken zygomatic processes of the temporals is accepted as approximately correct. The face, as indicated in the morphological description and by the index of facial flatness, 21.31, is not flat and can be described as extreme in this respect, since the index surpasses Woo and Morant's [10] mean for North American Indians by 4.6 units. The nasal breadth is moderate. According to indices derived from the measurements the skull is dolichocranial, hypsicranial, acrocranial, and on the border of metrio- and eurymetopy.

In cranial indices two of the female skulls are very close to the male skull; the third female, though probably within the range of the group, is just brachycranial. This third skull is hypsicranial, on the border of steno- and metriometopy, mesoprosopic, mesene, chamaerrhine, mesoconch, and brachyuranic. In general, it is safe to say that the female skulls would fit as well into other Sylvid series as the male skull.

The means of four Sylvid series are also given in Table III. The series from the Turner Group is the only Hopewellian one from Ohio available for comparison. The primary series is used here. As can be ascertained by reading across the table, it is closely related metrically to an early Woodland series from central Illinois. This early Woodland Sylvid series consists of all the crania of males from Fulton County sites that yielded type 1 Woodland pottery — sites F°7, F°10, F°12, F°13, and F°77, which have been classified in *Redis-*

[10] Woo, T. L., and Morant, G. M., "A Biometric Study of the 'Flatness' of the Facial Skeleton in Man," *Biometrika*, 26, Parts I and II (1934): 222–225.

covering Illinois[11] under the Morton and Black Sand foci of the Central Basin phase (Woodland pattern). This fairly homogeneous early Sylvid population was rather widespread over the eastern United States and forms the basis for the Hopewellian group. The male from the Porter mound fits in with these two series as well as can be expected.

It is, however, a different story with the developed Hopewellian groups in Illinois. In the sites where skeletal material is associated with types 2, *2a*, 3, *3a*, and 4 pottery and with the typical Hopewellian artifacts there is a strong brachycranial Centralid ("Gulf" type of Hrdlička) element represented. Comparisons have therefore not been made with those series.

The other two series in Table III represent the means of crania from the Anderson Village site at Fort Ancient — a group that has been classified as of the Anderson focus of the Fort Ancient aspect (Upper Mississippi phase) — and from the Maples Mills focus of the Woodland pattern. Both series are late prehistoric or protohistoric, and were selected to show that the same physical type lasted through to historic times in both southwestern Ohio and central Illinois. Again the close relationship to the two earlier series is unmistakable.

Incidentally, this relationship of the population of the sites of the Anderson — and the Baum — foci of the Fort Ancient aspect to the population of the Ohio Hopewellian sites may answer the question as to what happened to the people of the latter. In a physical-anthropological sense there is nothing against the possibility that a group like the Anderson Village people are the direct descendants of the Hopewellian, that they took over a culture brought from the south by a Centralid group with perhaps a Middle Mississippi manifestation, and that the culture resulting from the contact became what we now recognize as that of the Fort Ancient aspect, but that the southern Centralid invader remained relatively pure in the populations of the sites of the southern foci of the same aspect. The Madisonville group is one of these. For the descendants of the Hopewellian population in Illinois we should, on the other hand, have to look among Middle Mississippi groups or among historic tribes such as the Ojibway, where there is a strong Centralid element.

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[11] As cited in note 2.

HOPEWELLIAN POTTERY TYPES IN MICHIGAN

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IN MICHIGAN and Indiana there are a number of prehistoric burial-mound sites of sufficient cultural similarity to justify their classification in a single category, which I have elsewhere called the Goodall focus.[1] This focus, which has eight components, seven in Michigan (Brooks, McNeal, Norton, Converse, Gratten, Sumnerville, and Scott) and one in Indiana (Goodall), I assume to belong to the Elemental aspect of the Hopewellian phase.[2]

In order to provide a frame of reference in which to evaluate the pottery I shall first describe briefly the nonceramic traits characteristic of the Goodall focus. Some of these traits are conical earthen burial mounds, situated near rivers, rectilinear subfloor burial pits, the presence of artifacts in graves, extended burials, flexed burials, and bundle burials. The artifacts made of copper are ovate-oblong celts, trianguloid celts with truncated apexes, and awls sharpened at both ends. Large chipped-flint blades, small flint flake knives, and ovate, corner-notched, chipped-flint projectile points are also characteristic. The "ground-stone" objects are polished slate gorgets, four-sided or elliptical, with single biconical perforations, and polished stone platform pipes with curved bases. Other representative traits are split awls made from the metatarsi of deer, *Busycon perversum* shell containers, cut jaws of animals, perforated canine teeth of bear, worked sheet mica, twined fabric impressions, and the use of red ochre.

All of these nonceramic traits occur in any four or more of the eight components and therefore may be considered fifty to one hundred per cent characteristic of the Goodall focus. In addition, there are a number of other assumed Hopewellian traits which occur in

[1] Quimby, G. I., Jr., "The Goodall Focus, an Analysis of Hopewellian Components in Michigan and Indiana." (*In manuscript.*)

[2] The terminology and the system of classification have been described by W. C. McKern, "Midwestern Taxonomic Method as an Aid to Archaeological Culture Study," *American Antiquity*, 4: 301–313. 1939.

any one, two, or three of the components. These traits have been described,[3] however, and need not be considered for the purpose at hand, which is to classify the pottery representative of the Goodall focus.

As used in this essay, "pottery type" represents an average of a group of trait elements selected from a number of specimens which appear to be similar. However, most of the trait elements selected to represent the type can be observed on any specimen of it.

Because sherds are quantitatively different and therefore qualitatively different from whole vessels, an attempt was made in this study to classify the pottery in terms of whole vessels. With the information abstracted from complete specimens the sherds could be classified easily, and with a greater degree of certainty.

This classification is based specifically upon an analysis of thirty-three whole or reconstructed vessels and twenty-two sherds. The pottery groupings may have been affected unintentionally, however, by the writer's perspective on Hopewellian pottery in general. The vessels studied are in the possession of collectors or museums in Michigan and Indiana, and pictures of each artifact are filed in the Museum of Anthropology of the University of Michigan.

The pottery from the eight Hopewellian components belongs to five types, which in this paper have been labeled: "Hopewellian zone-stamped," "Norton crosshatched," "Goodall dentate-stamped," "Sumnerville incised," and "Brooks plain." The last four types are closely related to each other, and on a broader level of classification they could be merged into a single category. A sixth type discussed in this essay is the "generalized Woodland" cord-marked pottery found in these Hopewellian sites.

The diagnostic traits or unique characteristics which separate Hopewellian zone-stamped, illustrated in Plate I, Figure D, from all other types studied by the writer are as follows:

I. Rather abundant limestone tempering, most of which has been leached out of the paste, leaving angular cavities
II. Fine to medium texture
III. Smoothed to burnished surface
IV. Very well executed decorative techniques of:
  A. Fine-line incising
  B. Hemiconical punctating made from the left with a hollow point
  C. Rocked-dentate stamping

[3] Quimby, *op. cit.*

V. Very well executed decorative patterns on:
   A. Rim:
      1. Narrow band of fine-line closely spaced crosshatching, confined to convexly thickened or chambered upper rim
      2. Horizontal row of small closely spaced hemiconical punctate impressions made from the left with a hollow point, just beneath upper rim band
   B. Body: curvilinear zones, bounded by narrow shallow rounded incised lines and either empty or filled with units of closely spaced rocked-dentate stamp impressions; mostly confined to body lobes and generally alternate-repeating
VI. Within limits, a shape more or less uniform and differing from others in that these jars:
   A. Are always quadrilobate
   B. Are always convexly thickened or chambered in upper rim
   C. Have bottoms which are rounded or rounded and flattened

The vessels as a group are thin, averaging about 0.4 cm. thick.

The diagnostic features which differentiate Norton crosshatched, illustrated in Plate I, Figures F–G, from all other types are:

I. Poorly executed decorative technique of fine-line incising
II. Poorly executed decorative pattern of rather narrow rim band of closely spaced or somewhat closely spaced fine-line incised crosshatching and, just beneath this, a horizontal row of closely spaced poorly executed hemiconical punctate impressions made from either the right or the left (and not made with a hollow point)

This type seems to be an imitation of Hopewellian zone-stamped, yet, on analysis, it appears to be more closely related to the types Goodall dentate-stamped, Sumnerville incised, and Brooks plain.

The diagnostic traits of Goodall dentate-stamped, illustrated in Plate I, Figure B, are the following:

I. Decorative technique consisting of the use of a thick-toothed dentate stamp (in a few instances thin-toothed dentate stamps are used, and, in one, cord is used in the same way as a dentate stamp)
II. Decorative patterns on:
   A. Rim: rather wide band of closely spaced or somewhat closely spaced vertical (straight or curvilinear) or right-to-left–slanting dentate stamp impressions (cord impressions in one instance)
   B. Body: angular or curvilinear zones bounded by narrow or broad shallow rounded incised lines and either empty or filled with units of closely spaced dentate stamp impressions (in one instance cord impressions are used instead of stamp)
III. Within limits, a shape variable in regard to degree of upper shoulder constriction and bottom form, and with:
   A. Rim generally straight
   B. Lip generally flattened
   C. Thick vessel walls, averaging about 0.9 cm.

For the type Sumnerville incised, illustrated in Plate I, Figure C, the diagnostic traits are:

- I. Decorative techniques consisting of:
  - A. Rocker incising [4]
  - B. Narrow-line incising (on the rim)
- II. Decorative patterns on:
  - A. Rim: rather narrow upper rim band of closely spaced rocker-incised lines or of narrow shallow rounded horizontal closely to somewhat closely spaced incised lines
  - B. Body: curvilinear zones bounded by narrow shallow rounded incised lines and either empty or filled with units of closely spaced rocker incising; bottom of the vessel generally decorated also

The type Brooks plain, illustrated in Plate I, Figure E, is probably a component determinant, since it occurs at but one site. The diagnostic traits for this type are as follows:

- I. Decorative techniques consisting of impressing by means of a stick, either cord-wrapped or plain
- II. Decorative patterns consisting of:
  - A. Very narrow upper rim band of short vertical impressions which cut into outer edge of lip
  - B. Rather short horizontal intermittent sparse impressions along median line of rim

As has already been stated, the types Norton crosshatched, Goodall dentate-stamped, Sumnerville incised, and Brooks plain seem to be closely related to each other typologically. The characteristics which link these types together as a group and yet differentiate them from the type Hopewellian zone-stamped are:

- I. Grit tempering
- II. Medium or medium-coarse texture
- III. Smoothed or roughly smoothed surface
- IV. Within limits, more variable shapes, although still in range of small jars

The link traits or common characteristics of all five of these types, however, are evidenced in:

- I. Temper: grit, granitic, or limestone
- II. Surface treatment: roughly smoothed to burnished

[4] The term "rocker incising" denotes a very narrow line cut into the semi-hardened clay by a technique related to plain rocker stamping such as is found on some pottery types in the Lower Mississippi Valley, e.g. "Tchefuncte stamped," "Troyville stamped," or "Chevalier stamped." The techniques are closely related, but the results can be clearly differentiated, and therefore I wish to make the distinction. Rocker incising has somewhat the appearance of freehand incising in simulation of plain rocker stamping, yet seems to have been the product of a sharp-edged tool which was rocked in the same way as a stamp.

III. Decorative techniques: incising, punctating, stamping, and impressing
IV. Decorative patterns:
  A. Rim bands or horizontal rows
  B. Angular or curvilinear zones bounded by incised lines and either empty or filled with some decorative unit
V. Shape:
  A. Lips rounded, narrowed and rounded, rounded and flattened, or flattened
  B. Rims straight, straight to slightly flaring, and flaring
  C. Upper shoulders somewhat constricted, slightly constricted, and very slightly constricted
  D. Shoulders rounded
  E. Shoulder diameter slightly greater than mouth diameter
  F. Bodies short, distance from base to shoulder being about the same as shoulder diameter
  G. Vessels often quadrilobate
  H. Bottoms rounded, rounded and flattened, semiconoidal, and conoidal

TABLE I

Comparison of Pottery Types and Traits

Traits	Weight	Components							
		Brooks	McNeal	Norton	Converse	Gratten	Sumnerville	Scott	Goodall
Link traits by types									
Hopewellian zone-stamped or Norton crosshatched, Goodall dentate-stamped, Sumnerville incised, and Brooks plain, or all......	15	+	+	+	+	+	+	+	+
Norton crosshatched, Goodall dentate-stamped, Sumnerville incised, Brooks plain, or generalized Woodland, or all....................	4	+	..	+	+	..	+	+	+
Hopewellian zone-stamped or generalized Woodland, or both.................	3	+	+	+	+	+	+	+	+
Any one, all, or any combination of Norton crosshatched, Goodall dentate-stamped, Sumnerville incised, and Brooks plain......	4	+	..	+	+	..	+	+	+
Diagnostic traits by types									
Hopewellian zone-stamped..................	11	..	+	+	+	+	+	..	+
Norton crosshatched.......................	3	+	..	+	..	..	..	..	..
Goodall dentate-stamped...................	6	..	..	+	..	..	+	..	+
Sumnerville incised.......................	5	+	..	+	+	..	+	..	..
Brooks plain..............................	3	+	..	..	..	..	..	..	..
Generalized Woodland......................	2	+	..	+	..	..	+	..	+

The previously mentioned sixth type of pottery has not been analyzed in any detail. It is generalized Woodland, and future synthesis may provide a type concept for it. For purposes of the present study it has been classified entirely upon the basis of a cord-marked or malleated exterior surface, a characteristic of diagnostic value only with reference to the other types described here. An example of this pottery is illustrated in Plate I, Figure A.

Table I summarizes the data in a qualitative manner and weighs it in terms of the diagnostic and link traits of the pottery types.[5] All eight of the components share 18 of the 56 traits possible, six components share 37 traits, and four of the components have in common 44 of the 56 traits. Interpretation of this trait distribution is complicated by the uneven quality of the methods used to obtain and to preserve the collections. Had the excavation of all components measured up to modern archaeological standards and had the collections not been scattered, the number of traits common to all components probably would have been greater. I believe, however, that the distribution in Table I confirms the assumption that the pottery classified in this paper is representative of the Goodall focus.

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[5] In the usual comparisons of components by pottery type there is no indication of the degree of relationship among the types. Comparison by individual ceramic traits, on the other hand, indicates the degree of relationship, but submerges the identity of the pottery type in the morass of trait elements. I believe the method employed here retains the virtues of both systems and at the same time eliminates the confusion resulting from the use of either alone.

Hopewellian pottery types

A, Generalized Woodland; B, Goodall dentate-stamped; C, Sumnerville incised; D, Hopewellian zone-stamped; E, Brooks plain; F, Norton crosshatched; G, Norton crosshatched. The scale is variable

A HOPI VISIT TO THE AFTERWORLD

MISCHA TITIEV

IN THE myths of a large number of primitive groups in many regions of the world there occur tales dealing with individuals who return alive from visits to the realm of the dead. Dr. A. H. Gayton, who has made a comparative study of this aspect of mythology among the North American Indians, has proposed a twofold classification of such tales.[1] She suggests that stories in which a living person pursues and tries to retrieve a deceased mate or relative from the world of spirits should be called "Orpheus myths," and that similar narratives, lacking only the pursuit motive, should be known as "visits to the Afterworld." She points out[2] that myths of the latter class describe the fate of the dead and explain how man came by this knowledge, but that the Orpheus myths, which are by far the more popular, go still further in that they supply motivation for the journey and account for the break that exists between the world of the living and the realm of the dead.

Among the Hopi Indians of Arizona the Orpheus myth seems to be unknown, but visits to the Afterworld are frequently related. Sometimes the stories are told as if the events had occurred in the remote past,[3] but on other occasions the narratives appear in autobiographical settings. A vivid account of the latter type was secured by the writer at the village of Oraibi in the summer of 1932.[4] The narrator was Don Talayesva, a middle-aged Hopi who speaks fluent English and who is well versed in the orthodox traditions of his tribe. Don's

[1] Gayton, A. H., "The Orpheus Myth in North America," *Journal of American Folk-Lore*, 48 (1935) : 264.

[2] *Ibid.*, p. 285.

[3] See H. R. Voth, *The Traditions of the Hopi*, Anthropological Series, Field Columbian Museum, 8 (1905) : 109–119.

[4] The story was recorded during a field trip financed and sponsored by the Laboratory of Anthropology at Santa Fe, to which grateful acknowledgment is made. The field party at Oraibi, Arizona, was under the direction of Professor Leslie A. White, of the University of Michigan. Dr. Fred Eggan, of the University of Chicago, collaborated with the writer in securing the narrative.

visit to the dead was supposed to have occurred in the winter of 1907, when he was about seventeen years old. At that time he was attending the Sherman Indian School at Riverside, California; and he attributes his "adventure" partly to the shock of a recent bereavement (he had just learned that an older sister had died in childbirth) and partly to an attack of pneumonia, which had overcome him while he was grieving for his sister. He recalls that he had been taken to the school hospital and had been given careful attention, but that he had continued to grow worse, even to the point of discharging blood. His feet were "half dead," and he felt as if he were somewhere else, walking and traveling about like one in a dream. At times he had to be forcibly fed.

Every now and then a spirit [5] would appear and would say to Don: "Now, my son, you've got to eat or you will die. You are careless and want to die, but I will save your life if you listen to me." Apart from Don no one saw this spirit. It was very well dressed in a dancing skirt and sash, but it was barefooted and wore its hair down. It was in the shape of a tall man over six feet in height. It had a plain *nakwakwosi* ("prayer feather") in its hair, and carried a blue one in its left hand. (Blue is the color symbolic of the west among the Hopi. The path of the dead and the home of the dead are supposed to lie to the northwest of the Hopi pueblos.)

On Christmas eve a Hupa Indian girl remained away from the customary school entertainment in order to visit and care for Don at the hospital. She spoke tenderly to him and urged him to get well, for he had been begging the nurses to let him die because he was suffering so badly. That night Don saw a group of Hopi boys making faces and teasing him through the transom above his door, but Frank Siemptiwa (now the Oraibi chief's lieutenant at Moenkopi) chased them away. Then the door seemed to grow wider and narrower, wider and narrower. It became dark, and Don shut his eyes

[5] Don said that the native word for the spirit described in his story is *dumalaitaka*. He explained that the spirit was his guide and that it behaved as if it were his ceremonial father. According to him, it was customary for Hopi men to make their first prayer sticks during the Soyal (winter solstice) ceremony for their guides; but other informants used the word only when prompted, and they said nothing regarding the nature of the first prayer stick made in the Soyal.

It is interesting to note that Don's narrative contains many conventional ideas taken from the general pattern of Hopi culture. In each case, however, he tends to introduce them as if they were parts of a unique personal experience.

as if he were dead. At this point the spirit appeared and said: "Now your time is up. I'll let you travel out from here to the place where the dead people are. The path is already made for you to go by. I'll wait here to see whether or not you are going to come back, and I'll keep hold of you."

Don walked down the hospital stairs as if he were treading on air and soon reached the San Bernardino Mountains. He climbed halfway up until he saw a long tunnel, within which there was a sort of foggy light. Walking through the tunnel he came to a flat place where there was a mesa. Soon he reached the house at Oraibi where he had been born. The door was open, so he entered and saw his mother combing his father's hair. They did not see him, so he moved a sheep pelt over and sat down. He waited for them to speak or to offer him food, but they neither saw him nor spoke to him. After an hour Don's grandfather entered, but he, too, failed to see him. Don felt that his folks did not care for him, and that it was better to go back and eat the food that the nurses gave him.

He got up and started to follow the same road back. When he came to the Oraibi dam he noticed a big lizard crawling under a pile of rocks. As he drew near he saw, peeping out from the rocks, an ugly naked woman with dry lips, who appeared tired and half-starved. She said: "My grandson, give me water to drink and food to eat." Don replied: "No, I have nothing for you. Are you the one I saw as a lizard?" "Yes, my father is a lizard and I have two hearts.[6] From here to the place of the dead you'll see people like me. I'm one of those killing your people, but I'm not the one who is killing you."[7] "Well, I won't feed you," Don insisted. "Then," said the old woman, "spit in my hand and I'll drink it." "No," Don replied. Then she said: "I'll go with you. You have only one heart and will arrive safely. I wish I were like you." Don answered: "Never mind, you are too old."[8]

Don now went along rapidly without touching the ground until he came to the west point of a mesa. He looked up and saw nice

[6] In Hopi belief witches (*poakam*) derive power through intimate association with animals. Accordingly, each witch is said to have two hearts, one human and the other that of an animal familiar.

[7] Don identified the witch as Bakavi, one of his grandmothers. The Hopi believe that witches can exert their evil power only on relatives.

[8] There is an implication here that the witch was offering herself to Don as a bribe for his help.

regular steps, about eight feet wide, of a red color. Up these he climbed to the highest point of the mesa. There he saw someone wearing bells and a horn and carrying a spear in his hand. That was Kwanitaka ("Agave Man"),[9] who said: "My boy, you come in time. Hurry, look to the southwest and you will see two roads." Don looked and saw a narrow road about a foot wide on the right and a big wagon road sprinkled with corn meal and pollen on the left. Kwanitaka then spoke once more: "Take the left road. I prepared it for you and sprinkled it with meal and pollen. Now hurry and you'll find someone to guide you."

Don hastened down and saw summer birds and blossoms on the left side of the wide road. He went along rapidly following the Moenkopi trail, which he was used to traveling. Soon he came to Coal Canyon, and there he noticed some queer animals like zebras. As he approached he found that they were twelve clowns (*tcuka*), who had painted their bodies with alternate dark and light stripes.[10] The leader remarked: "Nephew,[11] you come in time. Take the left road, and we will wait till you return. Hurry back or they will bury you. When you get there you'll find someone who will guide you." They were having a good time, joking and teasing as clowns always do.

After leaving the clowns Don came to a steep mesa and "sort of floated down." Soon he arrived at Grand Canyon and realized that he was on a familiar road. Here he saw cactus and many coiled snakes, which made progress very hard on the right hand, *poaka* ("witch") road. On the left road there was good pavement. He saw many ruined and deserted houses, such as he has since seen

[9] The tribal initiation ceremonies of the Hopi are conducted simultaneously by four secret societies, one of which is the Kwan ("Agave"). Its members wear single-horned headdresses and claim the god of death (Masau'u) as their patron. Hence they play prominent parts in all stories of the Afterworld. In a First Mesa description of the realm of the dead, in *Hopi Journal of Alexander M. Stephen* (edited by Elsie Clews Parsons), pp. 826 ff. (Vol. 23 [1926] in *Columbia Contributions to Anthropology*), the name Tokonaka is used instead of Kwanitaka.

For an account of the tribal initiation see J. W. Fewkes and A. M. Stephen, "The Na-ac-nai-ya," *Journal of American Folk-Lore*, 5 (1892): 189–220.

[10] The Hopi have several types of clowns, differentiated by dress and behavior (Stephen, *op. cit.*, pp. 157–158, *et passim*). Very often the clowns provide comic relief during the performance of serious rituals.

[11] Clowning at Oraibi is controlled by the Eagle clan, whose adult men are Don's uncles. Hence the clown leader automatically addresses Don as his nephew.

when going for salt.[12] In time Don came to the end of the road, and looking down a steep canyon he saw "shiny stuff — might be the Little Colorado River." He also saw a folded blanket like one he used to wear as a little boy. On the walls of houses he saw many people sitting. Soon he heard a bell ringing, and the sound kept coming nearer and nearer until another Kwanitaka appeared from the west. He was well dressed in a white blanket, and approaching rapidly he said: "I waited for you all morning. I'll show you many things. Your time is not yet up. You are careless and don't believe where your people go when they die. You think dogs and burros and animals die and that's all there is to it. I'd like to teach you a lesson. This blanket is for you to ride." Don followed to the south, where he saw another Kwanitaka making red yucca suds in a big dishpan. The first Kwanitaka, the one from the west, made white suds, explaining: "The red is for those who do not return, but I'll wash you in this one so that you can return."[13] (White is the color associated with the east. The Hopi path of life runs southeast.)

After the head washing Don followed the Kwanitaka to the southwest, where rising black smoke was pointed out to him. He looked closely and saw that it was coming from the ground. He soon made out eight people standing two deep in each of the four cardinal directions. Those in front were naked and were arranged with a man facing north, a woman to the west, another man south, and a woman east. Behind these four naked people stood four clothed persons, each in back of someone of the opposite sex. Near by Don saw another Kwanitaka, who was tending a fire in a deep pit like a "place where you bake sweet corn."[14] Don's guide said: "Look close. Those in front are *poakam*. They killed the people standing behind them, and it is their turn to throw them into the fire." Then the Kwanitaka who had charge of the fire commanded:

[12] In former times the Hopi made dangerous expeditions to gather salt near the Little Colorado River, in the vicinity of the home of the dead. See M. Titiev, "A Hopi Salt Expedition," *American Anthropologist*, 39 (1937): 244–258.

[13] Whenever a Hopi undergoes an important change in status, the event is accompanied by head washing in yucca suds. Since death is regarded as such a change, the head of a corpse is washed prior to burial. Hence it was fitting for Don to expect to have his head washed when he visited the region of the dead.

[14] The type of oven in which the Hopi bake sweet corn is described by M. Titiev, "The Hopi Method of Baking Sweet Corn," *Pap. Mich. Acad. Sci., Arts, and Letters*, 23 (1937): 87–94. 1938. For the entire episode compare Voth, *op. cit.*, pp. 111–112.

"Get ready. You, from the north, throw him into the fire!" Thereupon the clothed woman who was facing north pushed into the pit the naked male *poaka* who stood in front of her. This procedure was repeated to the west, south, and east, a puff of flame arising every time a *poaka* was pushed into the fire. (The ritual circuit of the Hopi always runs north, west, south, and east.) Then Don's guide said: "These are dead about two hundred years. Every year they make one step and now they are here. Now, my boy, look in." Don looked and saw glowing red walls but no coals. In the walls there were several two-inch cracks, from which flames were pouring. As Don looked he saw four black beetles crawling about. The guide explained: "These are the four we saw thrown in. Now that's the end, and these beetles will stay here till their time comes. When you notice that a day is hazy, these are the ones who fly about and make it misty and not bright." (Later, it is said, the beetles fly back to these same pits.) [15]

"Now follow me," commanded Don's Kwanitaka. In a short time they came to a place where the road ended. "Look down!" ordered the guide. Don looked and saw big Masau'u coming up to meet him.[16] "He is the one who catches the people who come here," said the guide. "He is coming for you, but turn around and we'll push you back." The Kwanitaka who was making red soapsuds joined them, and the guide directed Don: "When we push you, run. Run as fast as you can and don't look back to see what is happening." They prodded him with staffs (?), and he rose from the ground and flew along to the place where the clowns were. They cried out: "Jump, Masau'u is gaining!" Don jumped and landed on the leader's chest, knocking him down. All laughed, and turning, Don saw Masau'u running back.[17]

Then the leader of the clowns said: "You have seen what you wanted to see. Now be careful, thoughtful, wise, and good. Treat people fairly. If you do this they'll think more of you and respect and love you, and lead you out of trouble. Otherwise they'll have nothing to do with you. Lots of people love you; that's what your

[15] Cf. Stephen, *op. cit.*, pp. 826–827.

[16] The Hopi believe that a person dies when Masau'u, the god of death, touches him. This attribute applies, however, only to the real or the big Masau'u, and not to any of the lesser supernatural characters who are associated with him.

[17] When Masau'u turned back the act meant that Don was not yet destined to die.

guide wants you to see. He's just punishing you so that you can see these things. We're looking out for you, we are your uncles. We'll see that no harm comes to you." [18] The clown leader continued: "You'll see an ugly person in your bed; that is your soul so don't be afraid. Lie down, put your arms around its neck, warm yourself, and you'll soon come to life." [19]

Don began to run back to the mountain, through the tunnel, to the foothill, and so back to the hospital. He entered quickly and saw his guide and the nurse sitting by his bedside. "Thank you," remarked the guide, "you come in time. Lie beside the ugly man and put your arm around his neck." Don obeyed instructions and soon began to grow warm. Then he heard many bees buzzing close to his ears, and gradually the sound grew louder. He freed his left hand, lifted his blanket from his face, and opened his eyes. At this the nurse said: "Well, my boy, you've come to life." Don looked around, and saw that it was Christmas morning, and the band was marching from building to building. (Don explained the buzzing sound as the band's music.) The Hupa girl cried, and holding his hand spoke to him: "Well, you've had a hard time. Your people don't know you passed away, but now you are well, and I'll keep you always." (This school romance did not result in Don's marriage to the Hupa girl.) The head nurse explained: "We were ready to put you into your coffin. We ordered it and it's on its way. But now look at what Santa Claus brought you." At the foot of his bed there were lying gifts of candy, fruit, and wearing apparel, including his uniform. He found that his face had been washed and his hair combed as if in preparation for putting him in his coffin.

Then Don took pity on himself, and he cried to get rid of his "sorrowful thoughts." He cried as he thought of his people and friends who did not know that he had died. After he had recovered and received a massage, his guide said: "Now, my boy, I taught you a lesson. Don't be careless any more. If you don't obey me I'll have to punish you again. I'll give you four trials, and then let you go and you won't come back to life. I love you, and that's why I watch you. Try to eat and be strong. Some day you'll be an im-

[18] Among the Hopi one's uncles are the disciplinarians of the family. The speech delivered by the clown leader is typical of the speeches made by uncles on such occasions as the marriage of a nephew.

[19] Cf. Voth, *op. cit.*, p. 118.

portant man in ceremonies. You'll be in the Soyal, where men make *pahos* ("prayer sticks") for everything. When you enter this ceremony make a *nakwakwosi* for me. I am your guide, I'm the one who leads and protects you. Many don't see their guides but I showed myself to you to teach you a lesson. Now I leave you." The nurses sitting there did not even see him. He turned, took four steps, and vanished. Don saw the *nakwakwosi* floating outside, but soon even that disappeared. "Now my guide is gone," said Don, "I'll never see him again."

In the summer of 1938, exactly six years after this narrative had been recorded, Don repeated his story in an interview with Dr. Leo W. Simmons, of the Yale Institute of Human Relations. Dr. Simmons has very kindly allowed me to see his field notes and to compare his version of the tale with the earlier account. Between 1932 and 1938 a number of minor variants had crept into Don's story. In Dr. Simmons' notes the death of Don's sister is described in greater detail and is attributed to a witch who was caught prowling about the house. The tribal affiliation of the girl who sat by Don's bedside, which was said in 1932 to have been Hupa, is later given doubtfully as Paiute or Walapi. The lizard which turns into an old witch is identified in the later version as the one who had caused Don's sister to die in childbirth. A new episode appears in the 1938 rendition. On the narrow, crooked road which evil people must traverse Don mentions having seen many bundles of Hopi clothing. These, he explained to Dr. Simmons, had been dropped by faithless wives who had received them in payment for adulterous relationships during life.[20]

In two places Don's later account employs phrasing of a somewhat stilted character that was foreign to his style in 1932. His original statement, in describing his first glimpse of the Afterworld, that he saw many people sitting on the walls of houses, he later changed to the following: "As I went along the road I saw many faces watching on my trail to Mount Beautiful, that is, to the judgment seat." (Note that Don has never been converted to Christianity.) In the 1938 version of his return to consciousness, Don has the nurse say: "Sonny, you passed away last night, but you did not cool off like a dead person. Your heart kept on beating slowly, and your pulse moved, so we did not bury you."

[20] A similar idea is implied in Voth, *op. cit.*, p. 117.

On the whole, a comparison of the accounts reveals that the basic elements of the story have remained virtually unchanged over a span of six years, in as much as the resemblances far outweigh the differences. This may be the result of frequent repetition, for Don tells his story to Hopi groups on numerous occasions.[21] In this way he refreshes his own memory at the same time that he helps his auditors formulate the Hopi concept of the Afterworld.

Since Don's story is autobiographical, the personal background of his supposed adventure affords an interesting subject for analysis. The episode occurred at a time when Don was unsettled and badly troubled in mind and body. He was about seventeen years of age, in the midst of the difficult period of adolescence, and for the first time in his life he was living away from the Hopi reservation, in a strange environment, where he missed the comforting influence and advice of his friends and relatives. Psychologically, he was at a crossroad. In September, 1906, about a year before his supposed experience, he had seen his native village split into two after many years of quarreling over the acceptance or the rejection of American culture.[22] Now, at school, he was offered countless opportunities of forsaking Hopi methods and adopting the white man's way, including conversion to Christianity. From his own statement it is evident that he was well treated and well liked at Sherman, and no doubt he was strongly tempted to accept the cultural pattern of his teachers. On the other hand, he had been brought up in a conservative family, and he could not lightly set aside his childhood training as an orthodox Hopi.

While he was undergoing this mental crisis, he received word that his sister had died. Thereupon his thoughts turned to the problem of death, which the Hopi attribute directly to witchcraft and supernatural agency. With these morbid considerations weighing on his mind he became ill with pneumonia. As his fever mounted he fell into a state of delirium or coma, during which his mental turmoil expressed itself in the vivid form of a visit to the Afterworld.

At the present time Don Talayesva is a man of about fifty, acting head of the important Sun clan, and still an orthodox Hopi. He

[21] See Titiev, p. 246 of the article cited in note 12.

[22] This episode, generally known as "the split at Oraibi," is described by E. Nequatewa, *Truth of a Hopi*, Bulletin of the Museum of Northern Arizona, No. 8 (1936). Flagstaff, Arizona.

firmly believes that his "experience" was granted to him in order to teach him not to be careless of the Hopi manner of life;[23] and he has remained one of the most loyal followers of Chief Tawaqwaptiwa of Oraibi, who has lost most of his adherents because of his stubborn refusal to forsake the customs and ceremonies which his "uncles" had taught him.

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[23] A Hopi is regarded as "strengthened" after returning from a visit to the Afterworld, as has been noted by E. A. Kennard, "Hopi Reactions to Death," *American Anthropologist*, 39 (1937): 491–496.

THE POSITION OF BLACKFOOT AMONG THE ALGONQUIAN LANGUAGES

CHARLES F. VOEGELIN

IN RECONSTRUCTING proto-Algonquian, evidence has been used chiefly from four languages still spoken in the Central or Great Lakes region: Menomini, Cree, Fox, and Ojibwa.[1] One may say that Shawnee is very much like Fox, and that Potawatomi has borrowed from Ojibwa to a degree yet to be determined, and make other statements of this order to show the relative position of the Central languages to each other. But the additional data contributed, for example, by recent studies of Shawnee and Potawatomi appear not to alter the essential picture of proto-Algonquian arrived at from a comparison of the four languages mentioned.

Whether the so-called Eastern Algonquian languages represent archaic features or special developments has not yet been decided. Phonemic stress, whether of an accentual or tonal nature, is an example in point. There is no question but that a phonemic representation of each word would mark stress for at least two Eastern languages, Penobscot and Delaware. Phonemic stress appears not to characterize any of the Central languages and has not been reconstructed for proto-Algonquian.

In the classification of Algonquian languages the validity of an Eastern group may be questioned because of lack of general peculiarities. But no one doubts that the three Western languages, Blackfoot, Arapaho, and Cheyenne, are each very different from proto-Algonquian, that is, from the reconstruction based on languages of the Central group. It still remains to be shown whether these Western languages share certain peculiarities or whether each is equally divergent from the others and from proto-Algonquian.

Arapaho and also Cheyenne (but not Blackfoot) have very special phonetic developments. Comparative phonology is not an easy

[1] See Bloomfield, Leonard, "On the Sound-System of Central Algonquian," *Language*, 1 (1925): 130–156.

task here, for the possibility of wholesale lexical borrowings from unrelated languages looms large; in contrast, vocabularies of the Central and Eastern languages are to a considerable extent obviously cognate. Isolation of the noncognate part of the Cheyenne, Arapaho, and Blackfoot lexicons would in itself be of service to Plains ethnographers.

The classification of the Western languages as divergent Algonquian is based on lexical differences and on comparisons of inflections.[2] Besides the inflections of Algonquian the morphology of the family as a whole is best characterized by the use of hundreds of "suffixes" or bound forms, some occurring after prefixes, some after stems, and some only at the end of themes. All sorts of meanings of things and of events are marked by such noninitial forms, which are by no means restricted to expressing grammatical notions; and many of these "suffixes" have related free forms. But terms for body parts, which always appear as noninitial elements, lack such related free forms and hence constitute a fairly homogeneous and conveniently small morphological division for preliminary investigation. Though certain specializations will be shown here, as have been shown in the descriptions of inflections, the impression remains that Blackfoot is not remarkably different morphologically from Central Algonquian languages. Its divergence therefore rests almost entirely on lexical differences.

1. As has already been stated, terms for body parts are never expressed by elements occurring in word-initial, but only by one or another kind of noninitial element. Many of the body-part terms occur in pairs, one form being used after possessive prefixes, the other in extended theme formation after free stems. Occurring also in theme formation, especially of transitive verbs, but having no formal relation to the doublets is a class of instrumental suffixes which includes designations of body part: 'by hand,' 'by feet,' etc.

2. Number of person and other inflectional distinctions are marked by suffixes, but person is always marked by prefixes for nouns (indicating possessor) and may be so marked for verbs (indicating actor). With names of body parts the prefix is placed before an element beginning in long or short *o*, rarely in *a*, and never in a consonant or an

[2] Michelson, Truman, "Preliminary Report on the Linguistic Classification of Algonquian Tribes," *Twenty-eighth Ann. Rep. Bur. Am. Ethnol., 1906–07* (Washington, 1912), pp. 221–290.

intrusive (intervocalic) *t*. Intrusive *t* occurs after personal prefixes in *–i* before verbs and before nouns beginning in a vowel (other than body parts). Compare *nonnikis*, 'my breast,' and *nitonnikis*, 'my milk.' The actual forms of personal prefixes before body-part elements are *n–* for first person (and exclusive 'our': 'mine and his'), *k–* for second person (and inclusive 'our': 'yours and mine'), *o–* (contracting with theme-initial *o–*) for third person, *m–* for indefinite person (translated without designating possessor). Examples are: *na·o·yi*, 'my mouth'; *kottsikiyowa·wa*, 'shoulders of you fellows'; *ottsikiyowa·wa*, 'their shoulders'; *mo·xksistona*, 'throat'; *nooxtsimmini·sts*, 'my arms'; *koˀksinno·nists*, *noˀksinno·nists*, 'our armpits' [inclusive, exclusive]; *mottsis*, 'gut'; *ottsis*, 'his gut'; *mooxkatsistsi*, 'legs'; *kooxsistsinno niks*, 'our toes,' 'our hoofs'; *ko·kitsinno·nika*, 'our fingers'; *nooxtaniˀsi*, 'back of my head'; *moˀkakini*, 'backbone'; *oˀkakiyowa·waists*, 'their backbones'; *mooxto·kis*, 'ear'; *ooxto·kiyowa·waists*, 'their ears'; *no·stoksinno·nists*, 'our faces'; *nomaokayinno·nists*, 'our chests.'

3. As has been said, virtually all postprefix body-part forms begin in *o*, short or long (vowel before *x* is unvoiced). In certain instances *–oox–*, *–o–*, or *–o·–* can be isolated as a preposed element. Compare *–taniˀs–* after *–oox–* in *nooxtaniˀsinno·nists*, 'backs of our heads,' and after *–tsa·ˀks–* in *nitsa·ˀkstaniˀissa·wa*, 'I burned the back of his head'; *–wapspi–* after *–o·–* in *mo·wapspi*, 'eye,' and after *–tsi·–* in *nitsi·wapspi·noˀsi*, 'I make eyes at myself,' 'I wear glasses'; *–niˀsi–* after *–o·–* in *ko·niˀsinno·nists*, 'our foreheads,' and after *–tsi·–* in *nitsi·niˀsi*, 'I have a forehead'; *–ksis–* after *–oox–* in *nooxksisinno·nists*, 'our noses,' and after *–tsaps–* in *nitsapsksisooxsi*, 'I flattened my nose'; *–(t)tsik–* after *–o–* in *nottsikinno·na·nists*, 'our shoulders,' and after *–(t)aispi(s)–* in *nitaispistsikaki*, 'I raised my shoulder'; *–piki·–* after *–oox–* in *nooxpiki·sts*, 'my ribs,' and after *–tsina·ni–* in *nitsina·nipiki·*, 'I have ribs'; *–tsimmi–* after *–oox–* in *nooxtsimmini·sts*, 'my arms,' and after *–(t)ai(s)–* in *nitaistsimmi·yi*, 'I washed my hands'; *–kits–* after *–o·–* in *no·kitsi·ksa*, 'my fingers,' and after *–tsikkaki·–* in *nitsikkaki·kitsa·wa*, 'I bumped his finger.'

So also theme-initial *–a·–* appears in the postprefix form *–a·o·yi–*, as in *ka·o·yinno·nists*, 'our mouths'; but the poststem form *–o·yi–* lacks preposed *–a·–*, as in *nitsa·ˀko·yissa·wa*, 'I burned his mouth.'

4. Postprefix forms in *–o–* may occur as poststem forms with theme-initial *–ox–* or *–o–* preserved. Compare *nooxpskinnaiˀi*,

'my chin,' and *nitsa·ˀkoxpskinnaiˀissa·wa,* 'I burned his chin'; *o·pikkina·nowa·waists,* 'their nostrils,' and *nitsa·ˀkopikkinˀissa·wa,* 'I burned his nostrils'; *kottsimˀaxkinno·nists,* 'our flanks,' and *nitsistsottsimˀaxki,* 'I have pain in my flanks'; *koˀkakininni·nists,* 'our backbones,' and *nitoxkittoˀkakini,* 'I have a curved backbone'; *no·kstso·ka·ni,* 'my hip,' and *nitsiko·kstso·ka·na·wa,* 'I broke his hip'; *koˀksis,* 'your armpit,' and *kitsimmoyoˀksi,* 'you have hairy armpits'; *o·kowan,* 'his stomach,' and *nitsa·ˀko·kowanˀissa·wa,* 'I burned his stomach'; *kooxkokinno·nists,* 'our necks,' and *nitsa·ˀkoxkokinˀsa·wa,* 'I burned his neck'; *kottoksinno·niks,* 'our knees,' and *nitsipakottoksa·wa,* 'I hit his knee'; *kowapiskkinno·nists,* 'our thighs (thigh bones),' and *nitsikowapisksissi,* 'I broke my thigh bones'; *nooxkinˀistsinno·nists,* 'our elbows,' and *nitsikkakoxkinˀistsa·wa,* 'I bumped his elbow.'

5. Doublets which show the postprefix form and the poststem form to be similar, or even identical, include such instances as those in which the theme-initial *–o–* or *–oox–* is preserved, perhaps in shortened form (4), or where the poststem form lacks the theme-initial *–o–* or *–oox–* of the postprefix form (3).

Beside similar doublets there is also occasionally a dissimilar or suppletive form for the same body part. Compare *–wapspi–,* 'eye' (3), and the poststem form *–apin–* in *nitsa·ˀkapinˀissa·wa,* 'I burned his eyes' (see also 7); *–niˀsi–,* 'forehead' (3), and the poststem form *–onˀisk–* in *nitsa·ˀkonˀiskssa·wa,* 'I burned his forehead.' Thus, also, compare *–ooxto·ki–* as postprefix form in *nooxto·kinna·nists,* 'our ears,' and the poststem forms *–oxto·ki–* and *–sto·ki–* in *nitsipakoxto·kiya·wa,* 'I hit his ears,' *nitaxkanisto·kiya·wa,* 'I pierced his ears'; compare *–ottoksi–,* 'knee' (4), and *–stoksi–* in *naipo·tsistoksissi,* 'I am knock-kneed'; compare, too, *–tsimmi–,* 'arms,' 'hands,' and *–kits–,* 'fingers' (3), with postprefix form *–oˀtsi–* and poststem form *–kinˀsts–,* 'arm,' 'hand,' in *noˀtsis,* 'my arm (hand),' *nitsipaksikinˀstsa·wa,* 'I hit his hand.'

6. Doublets which show the postprefix and poststem forms to be quite dissimilar are less common than the similar types (5). The dissimilar doublets may be formally unrelated, or, more characteristically, the poststem form may appear to be a fraction of the longer postprefix form; such partial resemblance may of course be accidental. Compare the postprefix form *–oˀtoka·n–* in *koˀtoka·nowa·waists,* 'your heads,' and the poststem form *–ixkin–* in *nitsa·ˀkix-*

kin?issa·wa, 'I burned his head'; *–o·stoks–* in *o·stokso·wa·waists*, 'their faces,' and *–ski–* in *nitsipaxtsi·pakskiya·wa*, 'I struck his face by mistake'; the postprefix form *–ooxpi·kini* and the poststem form *–i·kini* for 'tooth' (7, 9); *–o?kakini* (4) and *–kin–* (9) for 'backbone'; the postprefix form *–ooxkatsi–* in *kooxkatsinno·nists*, 'our feet,' and the poststem form *–ka–* in *nitsipaksika·wa*, 'I hit his feet,' *siksika*, 'Blackfoot Tribe.'

Doublets may refer to adjacent rather than identical body parts, although references are never too specific and tend to overlap. For example, *–ooxkokin–*, 'neck' (4), but, in poststem form only, *–stan–*, 'back of neck,' as in *nitsipakstana·wa*, 'I hit him on the back part of his neck,' *nitsa·tstana·wa*, 'I shaved the back of his neck.'

There are besides poststem forms and even postprefix forms lacking a correlative doublet. Thus *–o·to·ni–*, as in *mo·to·nis*, 'lip,' is known only in postprefix form, and *–stan–*, 'back of neck,' is known only in poststem form (see above).

7. In the sequence stem plus poststem form of body-part term, without a following instrumental, the relationship between stem and body-part term is usually of the "attribute-head" type, and the resulting word is an intransitive verb. Thus, the postprefix form *–apin–* (5) follows the stem *–(ts)istsi?p–* in *nitsistsi?papinni*, 'I have itchy eyes'; but the stem *–(ts)ists–* precedes either the postprefix form *–ooxpi·kini* or the poststem form *–i·kini* of the body-part term for 'tooth,' as *nitsistsooxpi·kini* beside *nitsistsi·kini*, 'I have a toothache (achy tooth)'; compare also *–ooxkokin–*, 'neck' (4, 6), and *a·pooxkokini·wa*, 'he has a white neck.'

8. The attribute-head construction when the resulting word is a noun is usually exocentric or superficially exocentric. Uhlenbeck gives numerous instances of this;[3] my own field notes show only a few examples.[4] Thus, as a compound of *–ksis–*, 'nose' (3), he records *páxpakskisi*, 'woodpecker (hitting nose)' and *ómaxkskisi*, 'Big Nose' [man's name]; to these should be added my example, *i·nooxksisi*, 'elephant (long nose).' But note endocentric translation of *om?axksisi*, 'a big nose,' *saaxksksisi*, 'a short nose.' As a compound

[3] Uhlenbeck, C. C., "A Concise Blackfoot Grammar, Based on Material from the Southern Peigans," *Verhandelingen der Koninklijke Nederlandsche Akademie van Wetenschappen te Amsterdam, Afdeeling Letterkunde*, Nieuwe Reeks (Amsterdam, 1938), Deel XLI, pp. 12–15, 198–201.

[4] Unless ascribed to Uhlenbeck, forms cited are from my 1935 field notes (Northern Blackfoot).

of *–sto·ki*, 'ear' (5), Uhlenbeck gives *kákanotstòki*, 'owl (who has large holes in his ears),' *ómaxkstóki*, 'mule (big ears),' and so on. With my postprefix form *–onniki–*, 'breast' (2), compare Uhlenbeck's poststem form *–kin–*, in *staókini*, 'Ghost Breast' [man's name], *manáukin*, 'new breast (young wolf).' Compare also *siksika*, 'Blackfoot Tribe' (6), and Uhlenbeck's *mékṡika*, 'Red Feet' [man's name]; *–kits–*, 'fingers' (3), and *omˀaxko·kitsis*, 'thumb (big finger).'

9. In the sequence stem plus poststem form of body-part term followed by instrumental or transitive suffixes (see 10) the body-part element serves to localize the "event" of the stem, or in Whorf's *Gestalt* terminology, the body part is figure relative to ground.[5] The resulting word is a transitive verb; the body part is not, however, the goal of the verb but rather that part of the goal (which may occur formally as another word) toward which the "event" of the verb as a whole is directed. Compare a poststem form used in such a construction, as *nitsipakixkinna·wa*, 'I hit him on his head,' and a postprefix form used with the third-person prefix as a separate word (2), the goal of a preceding transitive verb, as *nitsitaˀkiya·wa oˀtoka·ni*, 'I hit his head'[6] (see 10). Two words are not usually given in translation of an equivalent English sentence; almost all of my examples show the single-word construction with poststem form of body-part term, as *–i·kini–*, 'tooth' (7), in *nitssi·kini·yistsima·wa*, 'I washed his teeth'; *–oˀks–*, 'armpit' (4), in *nitsa·ˀkoˀksa·wa*, 'I burned him on his armpit'; *–ooxkokin–*, 'neck' (4, 6, 7), in *nitssox-kokiniyistsima·wa*, 'I washed his neck.'

Instead of instrumentals or transitive suffixes body-part elements in constructions of this type may precede intransitive formatives which generally bear some vague meaning, as *–ˀisina*, 'to be,' 'remain,' after *–o·pikkin–*, 'nostril' (4), in *nitsimmoyo·pikkinˀisina*, 'I have hair in my nostrils.' Note *–kin–*, 'back,' 'backbone' (6), before *–o·pi* in *nitsitapakino·pi*, 'I am sitting with my back to something.'

10. The relationship of instrumental suffix to prior members of a theme is not asyntactic but parallel to such two-word phrases as

[5] Whorf, B. L., "*Gestalt* Technique of Stem Analysis," Appendix to Part IV of *Shawnee Stems and the Jacob P. Dunn Miami Dictionary*, in Indiana Historical Society, *Prehistory Research Series*, 1 (1940) : 393–406.

[6] Such two-word phrases have the goal explicitly marked twice, by the verb and by the following noun: 'I hit him, his head.'

nom?oxtsiksiskowa·wa nooxkin?istsis, 'I bumped him with my elbow' (in contrast to example under 9, where the separate word for body part served as goal of the preceding transitive verb; see also 4).

Transitive verbs cited in the preceding sections can be listed schematically as *nitsa·?k(s)– . . . –(?)issa·wa*, 'I burned him on his . . .'; *nitsikkak(i·)– . . . –a·wa*, 'I bumped him on his . . .'; *nitsik– . . . –a·wa*, 'I broke him at his . . .'; *nitsipak– . . . –na·wa* beside *nitsipak(si)– . . . –a·wa*, 'I hit him on his . . . ,' and *nitsita–?kiya·wa*, 'I hit him'; *nitaxkan(i)– . . . –a·wa*, 'I pierced him at his . . .'; *nitsipaxtsi·pak– . . . –a·wa*, 'I accidentally struck him on his . . .'; *nitsa·t– . . . –a·wa*, 'I shaved him at his . . .'; *nitss– . . . –iyistsima·wa*, 'I washed him at his . . . .' Formally, the transitive inflectional ending *–a·wa* is preceded by an instrumental: *–(?)iss–*,' by means of heat,' *–n–*, 'by means of hand,' *–iyistsi–m–*, 'by means of water,' *–?kiy–*, 'by tool,' and, most commonly, a zero instrumental.

The following list gives the more productive instrumentals abstracted from various classes of themes in my small amount of material. It is taken from verbs with first-person actor (marked by prefix *ni–*) with intransitive ending, or transitive ending 'him' or 'it' as goal (marked by suffixes, as listed).

INSTRUMENTALITY	ANIMATE INTRANSITIVE	TRANSITIVE ANIMATE	TRANSITIVE INANIMATE
by hand	*–nnaki*	*–nna·wa*	*–nni?pa*
by hand	*–?taki*	*–?towa·wa*	*–?tsi?pa*
?	*–taki*	*–ta·wa*	*–to?pa*
? [causative]	*–ttsaki*	*–ttsa·wa*	*–ttso?pa*
by mouth (?) [in leading a horse?]	*–pixtaki*	*–piya·wa*	*–poxto?pa*
by feet	*–xkaki*	*–xkowa·wa*	*–xki?pa*
by seeing	*–nima*	*–nowa·wa*	*–ni?pa*
by heat	*–(?)issaki*	*–(?)issa·wa*	*–(?)issi?pa*
by tool	*–?kiyaki*	*–?kiya·wa*	*–?ki?pa*

CONCLUSION

Special developments of Blackfoot, in contrast to the Central Algonquian languages, include: complete avoidance of consonant initial forms (2); almost universal use of an initial *o*, which may ultimately be derived from the third-person prefix (2, 3); treatment of this *o*, sometimes combined with a following *x*, as a separable

preposed element (3); frequent retention of preposed *o* and *ox* in poststem forms (4); numerous instances of two poststem forms, one similar to the postprefix form, the other dissimilar (5); possibly a productive use of exocentric constructions (8); use of zero as a favorite form for the instrumental suffix (10).

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THE PLACE OF AGRICULTURE IN THE SUBSISTENCE ECONOMY OF THE SHAWNEE

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NO GREAT amount of specific information is available on which to base estimates of the amount of land under cultivation in eastern North America during pre-Columbian times, or of the relative economic importance of agriculture to the Indians of this region. In a recent monograph A. L. Kroeber [1] calculates that in the "agricultural east" about one third of a million acres were being cultivated prior to settlement by the whites. He bases this estimate on population figures for the area, number of bushels of corn produced per acre by native methods of tillage, and number of pounds of corn needed daily to sustain an individual. Allowing, as does Hinsdale,[2] a yield of fifteen bushels of shelled corn an acre, he finds that the yield from one acre would be sufficient to support one person a year. Therefore he assumes that the number of acres under cultivation in eastern North America was about equal to the number of persons inhabiting the region, or, roughly, some 350,000 acres. For the majority of the subdivisions of his large "Eastern" culture area Kroeber rates agriculture as "important" in the subsistence economy of the local tribes.[3]

Wissler,[4] in his map of the food areas of the New World, likewise stresses the preëminence of agriculture in the eastern half of the United States by referring to this section as the "Eastern maize area." In his text he calls attention to the "intensive agriculture" in the southeastern part of the region and to the reliance placed upon cultivated crops by the Iroquois and by certain Algonquian groups.

[1] Kroeber, A. L., "Cultural and Natural Areas of Native North America." *Univ. of Calif. Publ. Am. Archaeol. and Ethnol.*, 38 (1939): 146–147.

[2] Hinsdale, W. B., "Distribution of the Aboriginal Population of Michigan," *Occas. Contrib. Mus. Anthropol. Univ. Mich.*, No. 2 (1932): 24.

[3] Kroeber, *op. cit.*, Table 18.

[4] Wissler, Clark, *The American Indian*, Third Edition (New York: Oxford University Press, 1938), fig. 1 and pp. 238, 240.

Despite Kroeber's and Wissler's general statements, however, the picture is not yet entirely clear, and there still remains considerable doubt as to how much the Eastern tribes, or even the Southeastern ones, depended upon agriculture in their subsistence economy. In the social and ceremonial life of the Eastern Indians the importance of maize, especially, is frequently emphasized. Large group rituals, such as the Green Corn dance, bear witness to the significant rôle it played in ceremonial life, and numerous references in Eastern mythology to "Mother Corn" or to the three sisters, corn, beans, and squash, also give evidence of the stress laid upon agricultural products. But none of this material is of any great aid in judging to what extent the Eastern tribes relied upon cultivated plants for food. Nor do the accounts of many of the early travelers offer much specific information on this subject; what seemed to a sixteenth- or seventeenth-century observer a "vast quantity of maize" or a "great field" might be only a "small amount of corn" or a "little garden patch" when judged by twentieth-century standards. Neither subjective observations of this sort nor the social and ceremonial importance of agriculture can be used without corroboration in estimating its place in the subsistence economy of eastern North American tribes.

In this paper I wish to present field data on the economic aspects of agriculture in a specific Eastern tribe, namely, the Shawnee.[5] The Shawnee are one of the many tribes in whose native subsistence economy Kroeber rates agriculture as having been "important." They are a fairly representative Eastern group. Although culturally they affiliate mainly with the Winnebago, Fox, Kickapoo, Huron, Seneca, Delaware, and Nanticoke, they also have acquired some distinctively Southeastern traits, due to relatively late contacts with such Southern groups as the Creeks and the Yuchi.

The seasonal round of subsistence activities among the Shawnee of about two centuries ago was, according to informants, as follows. In the fall, from the end of September to the end of December, they were chiefly concerned with hunting deer, buffalo, bears, panthers, and turkeys. During these months the various Shawnee divisions camped in brushy river or creek bottoms, and groups of men, ac-

[5] Data from the Absentee, Eastern, and Loyal or Cherokee Shawnee were obtained during the summer of 1935, while I was doing field work among these groups as Indiana Fellow in Anthropology at Yale University.

companied by their wives, set out from these winter camps on two- or three-month hunting expeditions. The main camp served as a base to which hunting parties sometimes returned during the winter and also as a home for the old people and for children too young to be taken on the hunt. In January and February the men engaged chiefly in trapping. In March the different divisions removed from their winter camp sites to semipermanent bark-house villages located on higher ground beside a small creek or near flowing springs. In March and April fields near the villages were cleared, and in April the corn crop was planted. In May, June, July, and August the women attended to the crops and gathered wild plant foods. The men fished, chiefly during the month of May, and often left the villages for summer deer hunts. By August the corn had been harvested, and early in September preparations were under way for another winter camping season.

This outline of seasonal activities from informants checks with Henry Harvey's [6] extended, and reliable, account of the annual economic cycle of the Shawnee living near the Auglaize River in Ohio during the late eighteenth and early nineteenth centuries. During the latter century, after all the Shawnee had removed west of the Mississippi many of the old seasonal activities continued to be carried on, but because of the fact that a large part of the tribe were at this time leading a more or less wandering life there was less of an opportunity to maintain semipermanent summer villages.

Summer planting of crops along native lines continued, however, during the nineteenth century and is being carried on to some extent today, so that we are still able to muster data for gaining an insight into the part agriculture played in native Shawnee economy.

Five varieties of so-called squaw corn are planted by Shawnee women for household use.[7] They are: a red corn, a dark blue corn, a soft white corn, a hard white or "glass" corn, and a varicolored corn, "Osage corn." Each of these except the last has special uses; the Osage corn may be of more recent introduction than the other four, which appear to be old varieties.

In at least two Shawnee divisions, Kišpoko and Pekowi, tradition

[6] Harvey, Henry, *History of the Shawnee Indians, 1681–1854* (Cincinnati: E. Morgan and Sons, 1855), pp. 146–151.

[7] Some Shawnee men also raise field corn to sell or to feed livestock, but this is farming in the fashion of the whites and has little connection with native Shawnee agriculture.

demands that corn should not be planted until after the spring Bread dance, usually some time in April. Immediately preceding this dance a ceremonial ball game is played between men and women; four kernels of corn from each of the five varieties, or twenty kernels in all, are used as counters for the game. After the Bread dance is over the chief woman of the Kišpoko division takes the twenty kernels used in the ball game home with her and plants them in her garden plot, putting either two or four kernels in each hill. "This is the first corn to be planted; all the other women should wait upon this planting, then they can go ahead."

Several informants stressed the fact that the Shawnee "are supposed to raise corn every year, for food — and then they have to have it for the Bread dances in the spring and fall, too. They can't give a Bread dance if they don't have corn."

Sometimes, shortly before they are planted, the kernels of seed corn are greased lightly in the hands or in a dish with fat rendered from deer brains. "Corn never fails to make [mature] when it's treated like this. It's just like a woman; if she doesn't oil her hair it sticks out; if the kernels aren't greased, the corn will have short pointed leaves and be curled up and burned." The kernels can also be greased with the marrow from deer bones or with skunk grease; this latter "makes the corn taste good, and keeps it from getting wormy. It makes the cobs grow out long and full." Or else fish bones may be soaked in warm water, and the kernels dipped in this water, which "makes lots of ears on the stalks and protects the ears from burning if the weather turns hot in the growing season."

Some women soak the seed corn in water overnight, but according to an elderly informant they "only began doing this after the Civil War; they learned this from white people." The same informant said the Shawnee paid no attention to the phase of the moon in planting.

Corn and other crops such as beans and squash are usually planted early in the morning. A hoe with a blade made from shell or flint or a buffalo shoulder bone or a hacklike tool made from a forked stick used to be the chief implements employed in breaking up the soil and planting the seed. Two women always plant together; one "stirs the ground" with her hoe and makes a hole, about six to eight inches deep, which she fills with pulverized dirt to within two or three inches from the top. Her companion then drops from two to four kernels of corn in the hole; sometimes a bean seed or two is

also put in, so that the beans can climb on the cornstalks. The hole is then filled with dirt and the ground around it is hilled up to a height of about four inches to prevent water from collecting on the spot and rotting the seed.

The hills of corn are planted in rows, each hill being about four feet distant from the next. The rows are spaced about three feet apart, and are always planted in a west–east direction. Planting starts at the west end of a row, and the women work eastward; when one row is completed they walk back and start another row from the west. All informants agreed in their statements that no fertilizer is now, or ever was, put in the hills.

Corn patches are rarely fenced in, even today. One informant said that they were never fenced, horses being turned out to graze some distance away from the patches, so that the crops would not be destroyed. Another informant, from a different group of Shawnee, said that garden patches used to be fenced with brush fences.

As the corn grows the hills are hoed up and the weeds cleaned out. Irrigation of corn fields is never practiced, but magical methods are sometimes employed to produce rain. When the corn plants are about four feet high some fish bones or the shell from the back of a water turtle is taken to the center of the corn patch; a fire is kindled with flint and steel, and the bones or shell is burned. A prayer is offered to the Creator: "Let the corn not burn up; always send rain when it needs it." Because fish and water turtles come from the water, "the corn either gets rained on or escapes being burned up [by drouth]."

The soft corns mature early, roasting ears being ready by midsummer; the flint or hard corns mature a few weeks later. A woman gathers as many roasting ears as she needs from day to day to feed her family and to make roasting-ear bread; the remainder of the corn is left on the stalks to dry for later use.

The ears from the five varieties of corn planted by the Kišpoko chief woman after the spring Bread dance are gathered "the first thing" after they mature. The chief woman braids each variety separately and hangs the five lengths under the arbor at the dance ground. The following spring she will select, from this braided corn, the twenty kernels to be used as counters for the ball game; the remainder she will then use for seed, or in any other way she wishes.

A woman owns the crops planted in her patch. If her husband

wants four to six ears of corn to cook for a ghost feast for his dead relatives he gives his wife a piece of tobacco in payment. "But even if the woman owns the corn, she has to use it to feed her family; she can't trade it away for something that she wants for herself."

There was a certain amount of disagreement among informants as to whether men helped women with the native crops. One informant said that when the Shawnee were living in villages men and women worked together in the large field near the village, but other informants stated that women and young girls, only, did the work and that always, among the Shawnee, women cleared new fields and did all the planting and hoeing. Although each corn patch was owned individually, whether it was part of a common field or in a separate location, "all the women in a community would help hoe each other's plots." Some informants stated that both "men and women cut the brush and grubbed out the roots with stone hoes" in preparing a cornfield, and that men sometimes helped women plant the corn. After planting, men and women hoed the weeds. One informant stated that men even helped the women harvest the corn. Most of the gathering and all the husking and preparation of corn for eating was done by women.

The evidence shows that both in the old days and in more recent times men assisted the women to some extent in raising corn, but that agriculture was primarily a woman's occupation. A woman seldom worked alone in her field, although only she had absolute right to its products. The rôle men played in agriculture was a minor one; as an elderly informant stated: "Some men were poor hunters; they would trade corn for meat. Such men helped their wives in cultivating the land. But good hunters were always away, so their women raised the corn by themselves."

During the eighteenth century, when the Shawnee were living in Ohio in more or less distinct village groups, every village had, on the south side, one large field in which each biological, bilateral family grew its crops. A family or household group, numbering from "five to eight" individuals, was said to have cultivated "about one acre" in this field. No mention was made of additional separate family plots.

The statement that one acre sufficed for each household would be open to question except for the fact that Harvey[8] indirectly con-

[8] Harvey, *loc. cit.*

firms it. In summer, he relates, the Shawnee near the Auglaize River in Ohio "kept to their villages, where the women raised corn." But the corn they raised, Harvey observes, did not last long, being eaten up by the same fall. This being the case, the land planted for each family could not have been much more than an acre or so — which coincides with the amount the Shawnee themselves say was planted for a household a hundred to two hundred years ago.

So much for the late eighteenth and early nineteenth centuries. During the middle part of the latter century, when several of the Shawnee bands were leading a wandering existence west of the Mississippi River, the women "raised corn wherever they happened to be camping. They used new ground, choosing open, bushy spots, free of trees. They chopped and grubbed up the brush to clear it, and just cultivated little scattered patches."

One informant, now over sixty, described his mother's and grandmother's joint garden patch during this period prior to allotments as being "one half to three quarters of an acre. There were rows of beans, cabbage, Irish potatoes, pumpkins, and maybe ten to fifteen rows of corn in the patch. They'd raise all they wanted for a year on this patch, for two families of four and eight persons."

Another informant, who is some seventy-odd years old, said that, from her grandmother's descriptions, Shawnee corn patches of a hundred years or so ago were "very small. The brush on the land was cut and burned, and the next spring the roots were grubbed out with hoes. They didn't plant so much corn, because they weren't going to sell it. Sometimes close relatives combined their patches in what seemed like one big field, but each family had a separate part of the field where the women planted corn, beans, and pumpkins. Relatives would help each other in planting the field; they settled on the division of it after the crop had been put in, before it matured. Some leader would step out and assign plots to different household groups."

In describing the small Shawnee settlement in Seminole County, Oklahoma, where she was born, the same informant remarked, "Each Shawnee family had a little plot of ground, half an acre or so, which they cleared and cultivated. The patches varied in size; my father had a pretty big field; when he gathered corn it filled his corncrib full."

Another informant, also over seventy, said that the Shawnee

formerly "camped from place to place, occupying one spot for from four to ten years. If their gardens became old and the occupants were dissatisfied, they'd move. The villages, which were nothing more than camps, were about ten to fifteen miles apart. In 1854 Indian gardens were truck patches of one-half to one acre; four to five acres of corn was a big patch for an Indian in those days. They raised only what they ate at home."

For a slightly later period we have the following information concerning some Absentee Shawnee who did not want to accept individual allotments and who lived from 1867 to 1875 on Kickapoo land in a village called Rocky Place, four miles east and two and a quarter miles south of the present town of Tecumseh, Oklahoma. The population of Rocky Place, as estimated twice by an educated elderly informant who had visited the settlement in his youth, was "about two hundred persons." A government survey map of 1873 shows three fields under cultivation at Rocky Place when the Shawnee were living there. The acreage for the fields is given on the map as eighteen, fifteen, and twenty acres, a total of fifty-three acres, or a little more than one-quarter acre per person.

At the present time we find little increase in the amount of corn planted for household use. In 1935 a young married woman who served as one of my informants planted a garden to supply her family, which consisted of four persons. Her plot was about one acre in extent; half of it was in corn, the other half in cucumbers, tomatoes, onions, two varieties of beans, sweet potatoes, and melons. The father of the family estimated that, in order to keep four people supplied with corn for a year, four acres would have to be planted. This agrees with Kroeber's estimate of one acre a person each year.

For the Shawnee, however, all the field and source data indicate that in the eighteenth and nineteenth centuries Shawnee women cultivated from one-half to one acre yearly for a family of four or more persons. This gives one-eighth to one-quarter acre for each person. Even assuming that the amount of land tilled under purely native conditions was double the amount cultivated during the eighteenth and nineteenth centuries, we still should have to cut in half Kroeber's estimate of one acre a person. Clearly corn was not a staple food in the year-round subsistence economy of the Shawnee; for half of each year, at least, it figured only minimally, if at all, in their basic economy.

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ECONOMICS

NATIONAL DEFENSE AND THE BUDGET

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THE war in Europe, threatening at any moment to become another world-wide cataclysm, has aroused an insistent demand in an apprehensive United States for an expanded national defense program. The present Congress faces the task of deciding two different but related questions: (1) How much should be spent for defense? (2) How shall the program be financed? The latter is the problem to be considered here, though the most appropriate plan necessarily depends upon the amount of money to be raised.[1]

In authorizing national defense appropriations Congress encounters many other troublesome questions. What constitutes "adequate" defense? Are we spending more on national defense in order to (1) keep our country out of war, (2) protect ourselves if attacked, or (3) help the British win the present war? If preparedness is purely for defense, what do we propose to defend? Does defending ourselves mean protecting the Philippine Islands and maintaining a navy in the far Pacific as a warning to Japan? Does it involve the perpetuation of the Monroe Doctrine and, if necessary, the policing of the entire Western Hemisphere? Would the construction of naval and air bases in Central or South America by an unfriendly foreign power be tolerated? Does defense of the United States include protecting American shipping on the high seas against attack? Finally, does preparation purely for defense mean upholding whatever we choose to call our national interests and our national honor?

The answers to such questions have an important bearing on military expenditures. For example, a navy capable of waging war successfully four thousand or more miles out in the Pacific will cost much more than one designed to protect the continental United States

[1] This paper was presented on March 15, 1940, and thus was prepared before the momentous changes that followed Hitler's march into Holland and Belgium. It is confined to the fiscal aspects of national defense and purposely avoids the broader question of the economic effects of financing military expenditures.

against invasion. Similarly, an American army to fight in Europe will necessitate heavier outlays than one ample for domestic defense. If Congress decides to appropriate not more than two billion dollars for defense next year this sum can and should be raised by current taxation. On the other hand, if several billion are spent, as they surely will be if the United States becomes involved in war, then a large part of the program should probably be financed by borrowing.

Rightly or wrongly, there appears to be strong sentiment in this country for heavy defense expenditures, in the belief that strengthening our military power will help us keep out of war. Such expenditures were reduced sharply in the early 1930's, but later were greatly expanded. Exclusive of veterans' pensions and benefits and interest on war debts, they rose from 494 million dollars in 1934 to 1,140 million in 1939, and are expected to be approximately 1,519 million in the fiscal year ending June 30, 1940.[2] Numerous newspaper articles appeared in the latter part of 1939 urging that at least three billion dollars be spent at once to build up the nation's defenses. The contention was that a pressing need existed to double the air force, provide a larger and better-equipped army, strengthen the protection of the Panama Canal, and build sufficient ships for a two-ocean navy. President Roosevelt's budget message of January 4, 1940, recommended a total expenditure of 1,840 million dollars for defense in 1941, including 300 million designated "emergency national defense expenditures." This is practically double the total expenditures for national defense in 1938.

The President outlined a plan for financing his proposed program without causing the federal debt to exceed the statutory limit of forty-five billion dollars.[3] This maximum was established by the legislation which authorized federal borrowing during the World War. The last decade of continuous deficits had already resulted in a debt exceeding forty-two billion dollars, so that the existing margin for further borrowing was less than three billion. Since Secretary of the Treasury Morgenthau's suggestion last year that the debt restriction be increased to fifty billion aroused violent opposition, the

[2] Franklin D. Roosevelt, *Message to Congress Transmitting the Budget for Fiscal Year Ending June 30, 1941*. Jan. 4, 1940.

[3] The debt limit was raised to forty-nine billion dollars on June 25, 1940, when President Roosevelt signed the National Defense Tax Bill, authorizing the Treasury to sell four billion dollars in special "national defense notes" to pay for armaments until the taxes should come in.

President wished to avoid asking Congress to authorize borrowing in excess of the existing limit. Consequently, his 1941 budget recommendations for all purposes other than national defense were cut approximately 995 million dollars below the estimated expenditures for such purposes in the fiscal year 1940. He also asked that special taxes be imposed to yield 460 million dollars to cover the "emergency" expenditures for defense. Even so, the President contemplated a net deficit of 1,716 million, which would bring the debt practically to forty-five billion dollars by the end of the fiscal year 1941. His plan was based on the further assumptions of an increase of 382 million dollars next year in the yield of taxes already in effect, and the reimbursement of the Treasury by 700 million dollars from surplus funds held by government corporations.

President Roosevelt's fiscal proposals placed Congress in an uncomfortable dilemma. Rather severe reductions were recommended in unemployment relief and in aids to agriculture, which are dear to the hearts of many politicians, especially in an election year. If Congress voted aggregate appropriations in excess of the budget, thus increasing the deficit, it would incur the onus of raising the debt limit. Furthermore, the prospect of levying extra taxes, even for such an apparently popular cause as national defense, was most distasteful. Moreover, the President appeared to have the support of public sentiment in his demand for larger defense expenditures, so that political expediency forbade reductions in appropriations sufficiently drastic to solve the fiscal dilemma.

Nevertheless, two months after the budget was submitted, the House of Representatives had succeeded in slashing about 290 million from the total of 8,524 million dollars recommended by the President for the fiscal year 1941. Congressional leaders were prophesying that there would be no additional taxes and were hopeful that it would not be necessary to raise the debt limit. This was mere self-delusion, however, for the Senate had not yet acted upon the appropriation measures, and farm-state senators were demanding much larger subsidies for agriculture. At the present time (March 15, 1940) the total that will finally be appropriated is a matter of conjecture, but if we may judge by past experience a sum noticeably smaller than that requested in the President's budget will be most unusual.[4]

[4] The events in Europe during the summer of 1940 produced such strong feeling for more adequate preparedness that by August 5, 1940, Congress had

Let us now examine the relative merits of borrowing and taxation as methods of procuring funds for an expanded defense program in peacetime. There are no lack of advocates, in and out of Washington, of the borrowing policy. It is urged that an emergency is responsible for the needed additional outlay and that it is proper to borrow to meet such emergencies. Some contend that urgent need for immediate spending of large sums for national defense requires that the money be borrowed, because it would take too long to raise the funds by increased taxation. Others argue that since borrowing is so easy, it is foolish to risk arousing the hostility of the people against the national defense program by the more painful method of additional taxes.

Some claim that although there would be opposition to extending the debt limit, this measure would probably mean the loss of fewer votes at the next election than would the imposition of additional taxes. The results of the poll conducted by the American Institute of Public Opinion lead to the opposite conclusion. The question was asked, "If Congress decides to increase the army and navy, should this increase be paid for by extra taxes next year or by borrowing more money?" The replies of those polled with opinions on the question indicated that fifty-eight per cent favored extra taxes and forty-two per cent favored more borrowing.[5]

The weightier arguments appear on the side of those who prefer the payment of the cost of the defense program by imposing such taxes as may be necessary. If the United States fails to keep out of the present war the federal government will then need to borrow billions of dollars as well as to tax very heavily. If we are so unfortunate as to be drawn into war the taxes we shall pay, the deficits resulting from unbalanced budgets, and the rise in the national debt will dwarf in comparison the experience suffered in those respects in the last decade. Even if we stay out of war, as is so fervently hoped, *financial* is as vital as military preparedness.

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appropriated 13,824 million dollars and had authorized contracts for an additional 1,060 million. These figures included regular governmental costs, as well as special defense items. At the same date there was pending another defense bill providing a further appropriation of 2,237 million dollars and a contract authorization request of 2,733 million. Altogether, completed and pending expenditure proposals totaled 19,921 million dollars (*The Detroit News*, Aug. 5, 1940).

[5] *The New York Times*, Dec. 24, 1939.

A primary element of fiscal strength that may be of crucial importance is the ability of the national government to continue to borrow large sums if it ever should become really necessary to do so. Some people have the illusion that public credit is inexhaustible, but the experience of many governments has shown that this is not true. Even the United States during the last war found that it could not depend on people buying Liberty bonds entirely voluntarily. It had to resort to appeals to patriotism, and selling tactics were permitted which, in some instances at least, made the purchase of the bonds practically a forced loan. A government can confiscate wealth, either directly, by taking it, or indirectly, by inflation resulting from the issue of large batches of paper money (a kind of forced loan), but this would be an admission of the failure of borrowing upon a voluntary basis.[6] A breakdown of public borrowing would expose a vital defect in the supposedly heavy artillery of our fiscal arsenal.

With the federal debt rapidly approaching forty-five billion dollars, it behooves us to inspect this crucial line of defense. At its peak shortly after the close of World War I the federal debt was only twenty-five and one-half billion dollars, and this was reduced to approximately sixteen billion by 1930. The recent period of chronic deficits, resulting primarily from waging war on the depression, leaves us as a legacy a national debt nearly double the World War record.

If we increase this debt still further instead of raising the money from additional taxes are we strengthening our fiscal defense line or weakening it? Taxation is the foundation supporting public credit. Federal taxes provide the revenue from which debt service is paid on the national debt. When, and if, the present debt is reduced, revenues must exceed expenditures, so that there is a surplus for payment of principal. In other words, if we want a wider margin of safety there must be a Treasury surplus instead of a deficit, in order to retire part of this debt.

Throughout its history this country has followed the wise policy of rapid retirement of the national debt each time after its expansion. In the prosperous 1920's the federal debt was diminished by about nine billion dollars. In the meantime, however, the net borrowing

[6] A plan combining *compulsory loans* and taxes has been proposed for England. See Keynes, John Maynard, *How to Pay for the War, a Radical Plan for the Chancellor of the Exchequer* (New York: Harcourt Brace and Co., 1940).

of state and local governments increased by about the same amount. If federal taxes had not been reduced so much in that period, a much larger share of the national indebtedness could probably have been retired before the arrival of the depression deficits.

In the last war the financial problem was less difficult for two important reasons than it will be if we do become involved in the present struggle. One reason is that the national debt was only one billion dollars when we entered World War I. Nearly twenty-five billion was added at that time, but who really knows whether as much could safely be added now? Secondly, we had adopted the sixteenth amendment only a short time before the war, and the income tax became available as a new fiscal weapon of the greatest value. The income and excess-profits taxes produced nearly two thirds of the total tax revenue during the war period. Today the rates of the federal income tax in the upper brackets are already higher than they were during the World War, so that we cannot expect to obtain a great amount of new revenue from the rich, as we did then.

This raises the question of how to finance an expanded national defense program. The net deficit (excluding debt retirement) was 3,542 million dollars in 1939 and it is estimated that it will be 3,933 million in the fiscal year 1940.[7] If economic conditions improve, incomes will rise, and existing federal taxes should produce more revenue, but it would still be far from sufficient to cover all expenditures. This means that new revenue is essential. It might as well be recognized now that extra taxes are inevitable, especially if the federal government is to achieve a balanced budget. The real question, then, is not whether new taxes are necessary, but how more revenue can be obtained.

In his budget message the President did not specify the kind of taxes recommended to raise an extra 460 million dollars for defense. He expressed his preference, however, by stating: "In seeking additional sources of revenue, I hope that the Congress will follow the accepted principle of good taxation of taxing according to ability to pay and will avoid taxes which decrease consumer buying power." A few days later it was reported that President Roosevelt looked

[7] Total federal expenditures (excluding debt retirement) were 8,707 million dollars in 1939. They are expected to be 9,099 million in the fiscal year ending June 30, 1940.

with favor on a ten per cent supertax to be added to the regular income tax on individuals and corporations.[8] He favored this plan because of its mathematical simplicity, because it involved no complicated changes in tax rates, and because of the success of a similar levy which he had sponsored as governor of New York.

This proposal does have the merit of simplicity, since the income tax would be computed in the usual manner and the amount to be paid would be increased ten per cent. Furthermore, a special tax of this kind to be earmarked for emergency national defense expenditures could be repealed easily when the emergency had passed, without disturbing the regular tax structure.

The fact cannot be overlooked, however, that existing federal income tax rates on individuals now reach as high as seventy-nine per cent in the highest income bracket, and in addition there are graduated personal income taxes in a majority of the states. A ten per cent supertax would have the effect of increasing the degree of progressivity of the already steeply graduated federal income tax. This is because it would raise the effective rate in proportion to total income considerably more for those in the higher income brackets than for those now paying a relatively small amount of income tax. The supertax would not touch the great mass of people now exempt and would very inadequately tap the tax-paying ability of those in the middle income groups.

The application of a ten per cent supertax to corporations can hardly be justified as a tax according to ability to pay. There is no close correlation between the amount of tax paid and the tax-paying ability of the individual stockholders upon whom the burden would probably rest. Finally, the ten per cent supertax would produce far less than the additional 460 million dollars demanded by the President.

The personal income tax, which is generally conceded as best adjustable to individual tax-paying ability, can provide much more revenue than it has in the past if we are willing to make the sacrifice of lowering the personal exemptions and raising the rates, especially in the middle-income brackets. If more taxes are to be collected by the federal government, this is the most appropriate method.[9]

[8] *The Detroit News*, Jan. 11, 1940.

[9] See Strayer, Paul J., *The Taxation of Small Incomes* (New York: Ronald Press, 1939), Chaps. IV, VII; Simons, Henry C., *Personal Income Taxation* (Chicago: University of Chicago Press, 1938), pp. 219, 220.

As is not true of indirect taxes, the burden can be distributed more nearly according to the relative ability to pay of each person, and each person will know just how much more he is paying. The increase in the yield of the personal income tax would depend upon how far exemptions were lowered and rates raised.[10]

A few comparisons as to the amount of income tax now paid by people in the lower and middle income groups in Great Britain will illustrate what can be done by a nation that prefers to obtain most of its revenue from personal income taxes.[11] A couple with two children having a net income of $2,000 would pay $70 in England but pays no federal income tax in the United States. If the income is $4,000 this family would pay $721 under the British income tax but only $28 here. If the income is $20,000 the tax would be $8,047 in England, whereas it is $1,164 in this country. Of course, if we were to reduce the level of exemptions and raise the rates in the lower and middle income brackets the income tax would be more difficult to administer by the present system of individual returns. This problem could be minimized by emulating the British device of "collection at source" for the major part of income-tax collections.

Aside from increasing the yield of the income tax, the principal alternative methods of raising more revenue are the adoption of a national sales tax of some kind or a series of special taxes on specified commodities. Many commodities, particularly tobacco, liquor, and gasoline, are already heavily taxed. We would need a long series of such special, or "nuisance," taxes to get much revenue.[12] A national manufacturers' sales tax could produce large sums with less administrative trouble and expense than a number of commodity taxes.

[10] The National Defense Tax Bill adopted by Congress June 22, 1940, included the ten per cent supertax on incomes of individuals and corporations, and also reduced the personal exemption for single persons from $1,000 to $800; the exemption for married persons was changed from $2,500 to $2,000 (*The New York Times*, June 23, 1940). The exemption levels should be still lower, in view of the pressing need for revenue.

[11] *The New York Times*, Sept. 28, 1939; *The Detroit News*, Oct. 1, 1939.

[12] The National Defense Tax Bill of June 22, 1940, increased the taxes on alcoholic beverages, tobacco, and various other products. The Treasury Department estimated the total annual increase in revenue resulting from the adoption of the bill at 994 million dollars, of which 322 million would result from changes in the income tax law, and 302 million from the special ten per cent levy on incomes. The anticipated increase of 994 million in revenue is almost insignificant in comparison with the billions of dollars being spent for national defense.

Both these types of taxes are regressive, however, that is, they bear more heavily on the poorer classes in proportion to the size of their incomes, and therefore are contrary to the ability-to-pay principle of taxation. The burden would usually be shifted to consumers, in the form of higher prices than would otherwise exist. Since these taxes would be hidden in the prices paid for goods and services, they might appropriately be called "pickpocket taxes," for people would not know how much they really were paying.

It may be objected that the proposal to lower income tax exemptions means that the poor will have to bear more taxes just as they would if sales or commodity taxes were employed to raise extra revenue. This argument overlooks the fact that most of the increased revenue from the income tax would probably be taken from families with incomes between two thousand and twenty thousand dollars, as a consequence of steeper progression in the middle-income brackets. This group would pay more than they would if indirect taxes were used. Those with incomes below two thousand dollars, the bulk of the population, would pay less. The personal income tax exemptions would be lower, but the tax would be progressive according to size of income for all income groups, whereas a sales tax takes a larger percentage from a family with a thousand-dollar income than it does from those more fortunate.

This nation should stop living in a fiscal fairyland. If we insist upon spending large sums for national defense as well as for other purposes we should, as intelligent, patriotic citizens, pay for it now, not borrow all the money and so pile deficit upon deficit. But in striving for a balanced budget we must not attempt to get all the extra revenue from the rich. A more comprehensive and productive personal income tax is the most equitable solution.

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ECONOMICS AND WAR

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IT IS hardly necessary in the year 1940 to dwell upon the importance of the study of any aspect of war. War dominates the thinking of men and the policies of governments throughout most of the world at this very moment. War in its various aspects — preparation for war, the threat of war, the avoidance of war — has dominated thinking and policy almost continuously since 1914.

War has profoundly modified economic as well as political and social organization throughout the world during the past twenty-five years. Taxation in England, agricultural policy in Switzerland, the marriage rate in Germany, the place of communism in China, and the power of the army in the political life of Japan have all been directly influenced by war or by preparation for war. War threatens even more drastic changes in the near future. As students of the society in which we live we cannot avoid thinking about war. It must have some place in our thoughts unless we are to retreat from the world entirely, and the determination of that place is a part of economics as it is of political science and sociology.

No doubt the relation between economics and war has occupied the minds of some individuals as long as man has reflected upon economic problems. We are told by one writer that the word for war among certain peoples of ancient India meant a desire for cows. A land flowing with milk and honey was related to war among another ancient people. There is no more frank and ruthless document from the past than one which has descended to us from ancient China as the Book of Lord Shang, in which the whole duty of the people is represented to be military training and food production. The Book of Lord Shang has a very modern ring and it may be recommended to those who hold an easy faith in human progress.

The phrase "the sinews of war" has come down to us from the Middle Ages in Europe. It has been illustrated by the story of the medieval king who was told by his advisers — economic advisers no doubt — that three things were necessary to carry on a successful

war, the first being money, the second money, and the third money. And we have the current doctrine that an important cause of war is to be found in the existence of "have" and "have-not" states.

It is true that the relation between economics and war has not been dealt with as fully or as frequently as one might expect in the modern treatises and textbooks of the economists. It would be interesting to ask why. It may be that the economist is a humanitarian and dislikes to give an important place to war. It may be that war is viewed with repugnance because it is wasteful of life and of goods and is thus in opposition to the ethical implications of the economist's principles. But the subject has by no means been entirely neglected. In support of this statement I need name only a few men in the English-speaking world who have dealt with it. Consider the writings in this field of Norman Angell, E. V. Robinson, Thorstein Veblen, and Allyn Young. There is considerable literature on the subject in German, though much written during the past few years is not from the point of view of general speculation. The followers of Karl Marx have, of course, considered the subject. There are also the writings of those who have given attention to what Hobson was the first to call "economic imperialism." A young economist in Switzerland has just published a volume on war in the thinking of the economists and in the volume he has got no further than the beginning of the nineteenth century. He proposes to write two more to bring his study down to date.

It is not my purpose to review the literature of the subject or to engage in the critical discussion of the position taken by this or that writer. I desire to examine the relation between economics and war in a general and theoretical way. I realize the difficulties and dangers, but the problem is important, and I believe it to be urgent as well.

Confusion will be avoided and clarity promoted if certain distinctions are borne in mind. The first is that between economics as a social science, as a way of thinking involving certain principles and concepts, and economics as a convenient popular name for that which has to do with business activity and industrial production, for wealth and material welfare. When this distinction is not kept clear an argument may take strange turns.

A number of statements on economics and war have come to my attention, which may be combined and compressed into the following series of assertions. Economics is a method of reasoning based

upon the counting of costs against results. This, we are told, is what economizing means. If in the actual carrying out of any activity costs are consistently greater than results the activity must be regarded as noneconomic. In war — or at least in modern war — the costs are always greater than the results. War must therefore be regarded as noneconomic. It follows from this that the explanation of war is noneconomic, that war is not caused by a desire for wealth or material welfare, and that the cause is to be sought in the field of politics or psychology.

There may be more than one fallacy in this chain of propositions, but certainly there is this one, that economics means principles and concepts in the beginning and means wealth and material welfare at the end. Such reasoning could be applied in the following way. Crime does not pay: therefore the robber who holds me up at the point of a gun is not after my money. It seems plain that the economist cannot so easily divest himself of his responsibility for examining the relation between economics and war, that he cannot by such reasoning shift the whole burden upon his neighbor's shoulders, that he cannot, in short, win the game by his own default.

A second distinction must be made as a preliminary to a closer approach to the real problem. This second distinction is one between the different but related aspects of the science of economics. Economics may be said to have three divisions or parts, or, if you prefer, it may be said that there are three methods which are pursued within the field of economics. The three divisions are, first, the abstract, second, the realistic, and third, the formulation of policy. It is not to be supposed that the three can be completely separated. They support and complement each other. They represent a division of labor undertaken to create a single product, and the product is the whole body of knowledge to which we give the name "economics."

If now it should be maintained that abstract economics is the whole of economics it would then be possible to demonstrate, in quite a different way from the one dealt with above, that economics has nothing to do with war. I mean, of course, nothing to do with war in a causal or explanatory way.

If abstract economics is the whole of economics, and if it is quite independent of realistic economics and the formulation of policy, then economics may be held to be quite neutral toward policy. It may be maintained that it *must* be quite neutral. Economics, from

this point of view, may be defined as the solution of the logical problems involved in the application of scarce means to given ends.

Who, it may be asked, is the economist that he should judge these ends? They are what they are. The valuation of ends is no part of the economist's task. They are merely an important part of the data upon which he goes to work. It is true that adaptation of logic and method to different ends gives problems different forms. We may therefore maintain that we have an economics for each set of ends which is sufficiently separate to be dignified by a name of its own. So we may say that there is an economics of individual enterprise, an economics of family enterprise, such as we find in China, an economics of communism, and an economics of national socialism. The logic in each case may be held to be the same, and the economics — if we were heroically abstract — might be held to be the same economics. The important point, for the present, is that the economics is neutral.

Abstract analysis of this neutral sort is a necessary part of economics. This need not be insisted upon since it is probably well understood and commands general assent. It is not a part of my present task to demonstrate that abstract analysis is not the whole of economics. It is enough to say here that economics must be more than this if it is not to run the danger of becoming a mere intellectual plaything.

Let me now return to the relation of what I have called neutral economics to war. If economics is neutral toward policy then it is neutral toward war, as it is toward policy of any other sort. Since the prosecution of war may be regarded as an end — and who will doubt in the year 1940 that it may be so regarded? — there is an economics of war. One may even speculate upon the principles and propositions of such an economics. There is, no doubt, an optimum size of bomb depending upon such factors as the scarcity of materials, the varying costs of airplanes of different sizes, and the accuracy of the marksmanship. There is a best distribution of real income in a country surrounded by enemies so as to insure that selective starvation which will provide the longest retention within the country of the greatest military striking power.

In any community which may elect to go to war or which may have war forced upon it by the aggressive acts of others there is nothing to be said against economics as the servant of war. But, and

this seems to me to enforce my point, economics is more than a servant of war. A philosopher is more than a soldier, however noble or important the soldier's service may be, and what we want to know is how the philosopher explains war when he is no longer in uniform.

If abstract economics is not the whole of economics and if, therefore, economics cannot be said to have nothing to do with war — except perhaps to obey orders — we must push our investigation of the relation of war and economics to the other aspects of the subject.

The realistic method ought to be of first importance in any examination of this relation. The problem, it would seem, is one of studying a sufficient number of cases. Let the appropriate cases be selected. Let the economist make a careful study of history, collect the relevant statistical information, compare the course of events at different times, in different countries, and under different conditions. He ought to arrive at trustworthy generalizations and reach conclusions as to how far economic factors actually do play a part in war.

In general this seems the correct position to take, and much good work has been done by this method. Some of it may be suggested by the following questions: How far did the League of Nations succeed and how far did it fail in freeing and increasing international trade from 1920 to 1939? What regional economic agreements were entered into during this period, and were such agreements successful? How important are colonies to industrial countries? What has been the detailed history of the economic relations between important colonies and the colony-holding power? What are the new instruments of trade regulation? Have they made for peace or war? What has been the history of national policy toward raw materials? What has been the course of international investment?

Such questions as these may be studied with valuable results. But work of this sort seems always to move in the direction of more detailed examination and away from the broad generalizations which are involved in the relation between economics and war. There are, I believe, good reasons for this tendency, which has led to the charge that the economist has been giving his time and energy to the painstaking examination of the minutiae of a world that is falling to pieces about his ears.

In the first place, the cases which permit a broad general examination of our question are few. After all, great wars have not been numerous, and the wars concerning which we have abundant

information are still fewer. In the next place — and this is a usual condition in the investigation of social phenomena — a bewildering number of factors play a part. How is the economist to get forward when he faces the problem of explaining occasional events which involve the complex interrelations of a multitude of factors?

He must, it seems to me, proceed by bringing the factors into a tentative connected causal account. Such a connected causal account may be called an interpretation. His first step ought, then, to be the setting up of a provisional interpretation. This provisional interpretation is an effort of a realistic sort, but it will rest upon the abstract method also, and will carry with it proposals for the formulation of policy. Such proposals in the field of policy formation are an important part of an interpretation, for they make it clearer and they offer additional opportunities for testing its reasonableness. I ask you to consider certain provisional interpretations of events in the field of economics and war. In this way I hope to make my meaning clearer than it can be made by further general statement.

But before considering these efforts it may be well to pause in order to point out that the attempt to arrive at an interpretation requires what may be called imaginative courage, and it requires also a determination to go in for synthesis rather than analysis. I leave you to consider how far the social scientist fails to show the required imaginative boldness and how far he does show a greater zeal in analytical scrutiny than in synthetic construction.

A related question has been raised in connection with the training of men in the social sciences. It has been maintained that men trained in the natural sciences show greater imaginative courage than do the social scientists, that the social scientist takes more for granted and too easily falls into the comfortable error of supposing that truth may be ground out of a calculating machine or arrived at by piling one descriptive account upon another. These observations I put before you for what they are worth and turn to the next step in my exposition.

To illustrate the method of provisional interpretation I offer a few examples for your consideration. The first is a narrow one, without the broad sweep that the others show. For that very reason it is offered first.

Access to raw materials is obviously related to international difficulties and to war. Certain important raw materials are found

in the tropical colonies of great powers. The development of such raw materials has usually been by means of capital from the home country. Under these circumstances the problem of the distribution of products presents possibilities of international friction. The problem has not been satisfactorily solved by the acts of national states or of colonial powers. The fundamental difficulty may be held to lie in the complete political control. The world has seen the development of great corporations which carry on their activities in many countries and under many flags. Is it not possible to put certain important raw materials under the control of a new kind of great international corporation? They might be called chartered companies, as Paul von Zeeland, in discussing such a proposal, suggests. The shares of the companies might be widely distributed among the users of the raw material and in a way calculated to prevent the nationals of any one state from having control. The domicile of such a company might be a small state which is permanently neutral, such as Switzerland, Belgium, or Luxemburg. By this policy the advantage and prestige of colonial possession might be modified and an international political problem might be transformed into a world business problem.

A second illustration is provided by the current studies of Professor Wilhelm Röpke of the Graduate Institute of International Studies at Geneva.[1] Professor Röpke has studied the international economic relations of the past century and a half. He finds, by the familiar methods of realistic study, that this larger period breaks into two shorter periods. The first of these, to about 1914, was one of international economic integration. The second is one of international economic disintegration. He has worked out interesting indices of integration and disintegration. But he has found that he must go beyond realistic study to arrive at an interpretation of the events which he has studied. He offers as his fundamental explanation of the turn toward economic disintegration the rebellion of the mass of the people in Europe and America against the unsatisfying conditions of life under modern industrialism. He finds that the masses undertake to change these conditions by political action and that this leads to dictatorship and to war. Here we have an econo-

[1] The summary of Professor Röpke's findings is based on an unpublished manuscript, "Report on International Economic Disintegration," which states the results of research over the past two years.

mist whose work has led him to give an important place to the necessary and, in his opinion, the neglected background of economic activity. The exaggerated emphasis upon economic activity he finds to be one of the conditions making for economic disintegration. He offers, as you see, a sweeping interpretation of the failure of modern economic and political organization to provide either peace or a good life. His work has not progressed far enough to include more than a hint of policy formulation, but it is plain that it will go far beyond international economic policy in any narrow sense and that it will include proposals of a cultural and political sort. His explanation of the economic aspect of modern war required that he step boldly beyond his realistic generalizations into what I have called the field of interpretation.

A third example rests upon my own observation. Modern war I find to differ from war at earlier times in important respects and, among these, in its broad national basis and support. It may be that an explanation is to be found in the fact that international economic relations have influenced national groups more deeply and more generally in recent years. Since about 1870, when shipping by steamer became common, international trade has entailed the exchange of generally used commodities in large quantities, and in increasing quantities during most of these years. Examples of such commodities are wheat, coal, petroleum, cotton cloth, and shoes. In medieval times only a few persons were affected by international trade. In recent times the great mass of the working population has come to be involved in the consumption and production of internationally traded goods.

We must bring into the picture certain additional phenomena. The first is the growing political power of the mass of the people during the period since 1870, a power which rests upon education, modern means of communication, and political developments. The second is the possibility of conflict of interest among groups, classes, or regions within a country. And the third is the recurring phenomenon of depression and unemployment.

It is a most inadequate figure of speech, but we may think of these various factors to which I have called attention as bringing about internal and external pressures. When these pressures fail to be diminished or equalized the danger of war arises.

We may find a situation in which the political power of the

laborers is used to mitigate or alleviate by national policy the consequences of depression. Under modern trading conditions this causes effects upon other countries which may or may not have the power to retaliate. If they do not retaliate one sort of pressure comes into existence, and if they do there is another sort. It may be that growing international trade and growing political power on the part of the mass of the people are inconsistent, or inconsistent with peace.

Another example would be that of the necessity for adaptation to new circumstances on the part of a particular region or group or class within a country. This group or class may be in power in the country. A governing class may in this situation transform internal pressure into external pressure, and so intergroup problems within a country may be translated into international political problems.

War may thus be promoted, if not caused, by general national economic policies or by conflicts of interest within national economies. The important step is that internal pressure should become external pressure.

The limited truth in the doctrine of "have" and "have-not" nations seems to me best put into terms of internal and external pressure. Such an interpretation carries with it certain suggestions as to the formulation of policy. It may be that national economic policies ought to be discussed at international conferences of representatives of labor. It may mean that the international aspects of depression policy must be seriously taken into account. Local economic issues are not transformed into dangerous interstate and intercommonwealth political issues in the United States or in the British Empire. By what means is this avoided? And finally we may be forced to choose between real international economic organization and greater national self-sufficiency.

This final interpretation carries with it an inadequate answer to the problem which was set in the beginning. It does, however, show that the problem cannot be made either narrow or simple. A satisfactory reply to the question as to the place of economics in modern war involves more than economics. This is to say that the formulation and the testing of a true interpretation calls for the coöperation of social scientists from a number of fields.

Let me set down the conclusions in a series of brief statements:

1. The problem of the relation between economics and war is not avoidable.

2. It cannot be dealt with by the abstract method alone.
3. It resists attack by means of simple realistic generalization.
4. It demands interpretation in which the provisional formulation of policy plays a part.
5. Interpretation calls for coöperation with the students of other aspects of society.

May I repeat that synthesis is required, and a certain imaginative boldness. If the economist is not a scientist, by which I mean a philosopher with a free mind, he will become a technician in the service of policy in which he does not really believe.

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LANGUAGE AND LITERATURE

THE *PICTA POESIS* OF BARTHÉLEMY ANEAU: A LITERARY CURIOSITY OF THE SIXTEENTH CENTURY

FRANK OLIN COPLEY

BARTHÉLEMY ANEAU (*c.* 1505–61) describes in the following words the sentimental genesis of his *Picta Poesis:*[1] "With Matthieu Bonhomme, printer, of Lyons, I boast no small degree of friendship. At one time I entered his shrine of the Muses for a friendly call and there chanced upon a number of small pictures engraved in copper. When I asked him their purpose he replied that they had none, since he was not in possession of the texts which accompanied them. If he had ever had any such, he affirmed, he had lost them. It was my opinion that pictures like these had not been drawn to no purpose; accordingly I took upon myself the task of recalling them from the mute and dead to voice and life . . . . And so my task began, progressed, and at last was completed in Latin and some Greek verse . . . . I did not, however, strive so conscientiously to determine what that speechless illustrator, whoever he was, had in mind, as to devise like a teller of tales a text which seemed to me suitable to the pictures . . . . This I thought was the sole task entrusted to me: that the verses I composed should be in harmony with the pictures."[2]

[1] *Picta Poesis, ab authore denuo recognita, Lugduni, apud Matthiam Bonhomme,* 1556. (Hereafter abbreviated as *P.P.*) The first edition, which I have not seen, was published in 1552; see John L. Gerig, "Barthélemy Aneau, a Study in Humanism," *Romanic Review,* 1 (1910) : 182–183.

[2] "Cum Agathandro Lugdunensi Typographo mihi nonnulla est necessitudo, cuius ergo familiariter aliquando Musaeum eius ingressus, incidi in aliquot imagunculas in aes incisas. Quarum ego usum cum essem percontatus, is nullum esse respondit, quod inscriptiones ad picturam alludentes non haberet; aut si quas habuisset, sibi periisse adfirmavit. Ibi ego tales eiconas non temere effictas esse ratus, recepi me ex mutis, et mortuis, vocales, et vivas effecturum . . . . Itaque statim coeptum est opus, in eo progressum, et tandem peractum versibus Latinis, nonnullisque Graecis . . . . Quamquam non adeo anxie laborans coniectari quid Agalmatographos ille Aphonos (quicumque fuerit) in animo habuisset, quam quod mihi esse imagini aptum videretur, id μυθικῶs ad-

The little book is of mediocre quality and of slight importance, but charming in its grace and wit, and of no small interest as the *jeu d'esprit* of a man prominent in his own day as a literary figure and pedagogue. Born at Bourges of well-to-do parents, Aneau received his education at the university in that town, where he studied under two great teachers, Simon Dagobert and Melchior de Wolmar. He taught rhetoric in Lyons at the Collège de la Trinité, and in 1542 became its director. Zealous in obtaining the very best men for his staff, he raised the Collège to a position of great importance and influence. He pioneered in the movement to teach French in the schools, in which at that time instruction was carried on exclusively in Latin — and not very good Latin, in his opinion. The welfare of the school was always his prime concern; he worked constantly to improve the salaries of the teachers and the comforts of the students. The latter were suffering, when Aneau took office, from an insufficiency of bread and from the cold clamminess of the rooms in which the classes were held. In the school Aneau's popularity was unquestioned; the town magistrates, too, thought very highly of him. But the populace held him in suspicion because of his liberal religious views; it was commonly thought that he leaned dangerously toward Protestantism and that he was infecting the student body with this heresy. In 1561, as a religious procession was passing the Collège, a stone was thrown at the Holy Sacrament; the incensed crowd, blaming Aneau and his supposed teachings for the sacrilegious act, broke into the school and killed him.[3]

His works were numerous, all of them in the stilted rhetorical style of the conservative writers of his day. It is interesting to note that he placed a high value on the use of theatrical presentations as an educational medium and wrote several plays which the pupils in the school performed, chiefly at the Christmas festivals.

Aneau was in his late forties when he chanced on the engravings

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fingere . . . . Idque mihi negotii credidi solum dari, eiconibus ut convenirent, quos fecissem versus" (*P.P.*, *Aetiologica prophasis*, pp. 3–4). The reader will notice in the last sentence quoted the obvious paraphrase of Terence, *Andria* 2–3.

[3] This account of Aneau I have drawn from two sources: Gerig, *Romanic Review*, 1 (1910): 180–207, 279–289, 395–410; 2 (1911): 163–185; 4 (1913): 27–57; and Warner F. Patterson, *Three Centuries of French Poetic Theory* (University of Michigan Publications, Language and Literature, Vol. XIV [Ann Arbor, 1935]), Part II, 366–388. See also Larousse, *Grand Dictionnaire universel au XIX*[e] *siècle* (Paris, 1866), I, 344, "Aneau."

which inspired him to write the *Picta Poesis*.[4] A glance at them suffices to show why they aroused his interest and curiosity. Artistically they are on no very high plane, but they are obviously intended to illustrate various texts, and not to stand alone. The great bulk of them seem suitable for a book on mythology, possibly for Ovid's *Metamorphoses*, for we find clear representations of Hermaphroditus and the Salmacian fount, Actaeon turning into a stag, Daphne becoming a tree, Narcissus gazing fondly on his image in the waters (with the flower destined to bear his name springing up, in delightfully naïve style, just behind him), and the story of Echo (in which, as the girl utters a fond "Ah," the rocks respond, appropriately, "Ha"). Quite a number appear to be purely contemporary in their subject matter; they depict, for example, the slaughtering of a pig, the bursting of a cannon, a cockfight, a game of tennis, and a man fishing. In nearly every case they are of a character to pique the curiosity of their casual examiner. One can easily imagine that Aneau, long inured as he was to drawing morals from any and every situation for the benefit of his pupils, was instantly beset upon viewing the pictures by two titillating questions: What moral did these pictures illustrate? and What moral can *I* extract from them?

His curiosity thus aroused and his literary and pedagogical abilities thus challenged, he set about his task, and, as we should expect, gave to nearly every picture some ethical interpretation. It is no more than natural that his verses should be full of allusions to and borrowings from the Greek and Latin classics; indeed, in his Preface he states openly that his lines were drawn "partly from my own imagination, partly from the best authors of both tongues."[5] Again, as we should expect, Vergil, Horace, and Ovid are the authors most often used; I find further one borrowing from Juvenal and one reference to the *Metamorphoses* of Apuleius. There are passages taken from Homer's *Iliad* and *Odyssey*, and by some odd chance a fragment of Choerilus of Samos found its way into the book, probably from an anthology. But the classical tradition is really fundamental to

[4] Although Aneau professes not to know who made the cuts, Gerig (*Romanic Review*, 2 [1911]: 169) identifies the artist as Salomon Bernard, "*dit le petit Bernard.*" The technique shows clearly enough that they were woodcuts; Aneau's "*imagunculae in aes incisae*" (*op. cit.*, p. 3) were doubtless copper engravings made by the printer from the originals.

[5] *P.P.*, p. 4: "*partim ex meis conceptibus, partim ex optimis utriusque linguae autoribus desumptum.*"

the poems as a whole. A more thorough study of its sources would doubtless reveal many further echoes of Ovid, Horace, and Vergil, as well as passages inspired by Cicero, Livy, Sallust, and Catullus.[6]

[6] The following is a list of sources for the most obvious borrowings:

Vergil: *P.P.*, p. 53: "igneus est animis vigor et coelestis origo," cf. *Aeneid* 6.730 : "igneus est ollis vigor et caelestis origo"; *P.P.*, p. 59: "saxosi montes," cf. *Georgics* 2.111: "saxosis montibus"; *P.P.*, p. 75: "quosque fame errantes in sylvas cogit egestas rapto viventes, atque latrocinio," cf. *Aeneid* 7.748–749: "armati terram exercent semperque recentis convectare iuvat praedas et vivere rapto"; *P.P.*, p. 78: "motus incompositos dat," cf. *Georgics* 1.350: "det motus incompositos" (see also *P.P.*, p. 106, "dat motus incompositos"); *P.P.*, p. 86: "Scyllam ergo finxit Homerus candida succinctam latrantibus inguina monstris Dulichias vexasse rates et gurgite vasto, ah, miseros nautas canibus lacerasse marinis," cf. *Eclogues* 6.74–77: "quid loquar aut Scyllam Nisi, quam fama secuta est candida succinctam latrantibus inguina monstris Dulichias vexare rates et gurgite in alto, a, timidos nautas canibus lacerasse marinis"; *P.P.*, p. 90: "at securus agit cui mens est conscia recti," cf. *Aeneid* 1.604: "et mens sibi conscia recti."

Horace: *P.P.*, p. 21: "Epicuri de grege porcus," cf. *Epistles* 1.4.16: "Epicuri de grege porcum"; *P.P.*, p. 56: "sic et amica procax hedera formosior alba, lentis adhaerens bracchiis," cf. *Epodes* 15.5–6: "artius atque hedera procera adstringitur ilex, lentis adhaerens bracchiis"; *P.P.*, p. 57: "infoelix operam perdas, ut siquis asellum in campum doceat parentem currere freno," cf. *Satires* 1.1.90–91: "infelix operam perdas, ut siquis asellum in Campo doceat parentem currere frenis"; *P.P.*, *ibid.*: "auriculas demittit iniquae mentis asellus," cf. *Satires* 1.9.20: "demitto auriculas, ut iniquae mentis asellus."

Ovid: *P.P.*, p. 20: "quid magis est durum saxo? quid mollius unda? dura tamen molli saxa cavantur aqua," cf. *Ars Amatoria* 1.475–476: "quid magis est saxo durum, quid mollius unda? dura tamen molli saxa cavantur aqua"; *P.P.*, p. 34: "frigida cum pugnant Calidis, humentia siccis, mollia cum duris, sine pondere habentia pondus," cf. *Metamorphoses* 1.19–20: "frigida pugnabant calidis, umentia siccis, mollia cum duris, sine pondere habentia pondus."

Juvenal: *P.P.*, p. 97: "quod peregrina dicere libertas audet in historia," cf. *Satires* 10.174–175: "quicquid Graecia mendax audet in historia."

Apuleius: *P.P.*, p. 95: "dicere quos merito licet inversos Apuleios, nam facie humana, caetera sunt Asini," cf. *Metamorphoses* 3.26: "ego vero quamquam perfectus asinus et pro Lucio iumentum sensum tamen retinebam humanum."

Homer: *P.P.*, p. 29: "*οὗ γὰρ ἀπὸ γλώσσης μέλιτος γλυκίων ῥέεν αὔδη* [*sic*]," cf. *Iliad* 1.249: "*τοῦ γὰρ ἀπὸ γλώσσης μέλιτος γλυκίων ῥέεν αὐδή*"; *P.P.*, p. 87: "*μὴ σύγε κεῖθι τύχης* [*sic*] *ὅτε ῥοιβδήσειεν, οὐ γὰρ κὲν ῥύσαιτο σ' ὑπ' ἐκ κακοῦ οὐδ 'Ενοσίχθων ἀλλὰ μάλα Σκύλλης σκοπέλῳ πεπλημένος ὦκα νῆα παρεξέλαιαν, ἐπειὴ πολὺ φέρτερον ἐστὶ ἓξ ἑτάρους ἐν νηὶ ποτίμεναι* [*sic*] *ἢ ἅμα πάντας*," cf. *Odyssey* 12.106–110: "*μὴ σύ γε κεῖθι τύχοις, ὅτε ῥοιβδήσειεν· οὐ γάρ κεν ῥύσαιτό σ' ὑπὲκ κακοῦ οὐδ' ἐνοσίχθων. ἀλλὰ μάλα Σκύλλης σκοπέλῳ πεπλημένος ὦκα νῆα παρὲξ ἐλάαν, ἐπεὶ ἦ πολὺ φέρτερόν ἐστι ἓξ ἑτάρους ἐν νηὶ ποθήμεναι ἢ ἅμα πάντας.*"

Choerilus: *P.P.*, p. 20: "*πέτραν κοιλαίνει ῥανὶς ὕδατος ἐνδελεχείῃ*," an exact quotation of the fragment. See A. F. Näke, *Choerili Samii quae supersunt* (Lipsiae, 1817), pp. 169–177.

The elegiac distich is the meter preferred for the great bulk of the poems, but there are five in dactylic hexameter, three in the first Pythiambic, three in iambic dimeter, two in iambic trimeter, and one in hendecasyllables. Aneau handles all these meters in a wooden manner; his use of elision is none too skillful, and there are occasional metrical lapses.[7] The verses often give the impression of having been pieced together with the help of a *gradus*, as if the writer were unable to free himself from classroom practice. One suspects all along that he was much more at home in the vernacular and that his use of Latin is a concession to scholastic tradition rather than the result of natural preference.

In subject matter the poems have a range much wider than that of the engravings to which they are appended. The latter, as has been said, are largely mythological in character, but the moral interpretations given to them range over the fields of religion, human conduct, education, and politics. Running throughout the book like a subdued leitmotif is a curious note of misogyny. Many an innocent little classical scene is perverted into a diatribe on the wickedness — or at best worthlessness — of women. One of the more successful of these is attached to a picture showing a man restraining a satyr from embracing the flames of a fire:

MULIEREM TANGERE, MALUM

Rusticus algentem boreali frigore Faunum
  In sua deduxit tecta laremque foci.
Montano Satyro (quem numquam viderat) ignis
  Pulcher et aspectu visus amabilis est.
Viderat hic solem; similem esse videbat et ignem
  Soli: quo quid habet Mundus amabilius?
Ergo ratus Solem media fornace camini
  Illapsum domui semiferus satyrus,
Protinus amplecti voluit, dare et oscula flammae.
  Rusticus at cohibens, hunc ita corripuit:
"Parce, nisi abstineas tibi barba cremabitur, Hirce.
  Quodque vides pulchrum noveris esse nocens.
Namque videre procul iuvat, at prope tangere laedit.
  Contactu abstineas; intuitu fruere."
Haec adolescentes lascivos fabula pulchrae
  A Veneris flammis admonet abstineant.
Pulchram etenim formam, sub qua muliebre venenum est,
  Ut vidisse placet, sic tetigisse nocet.[8]

[7] For one of these he apologizes in a marginal note, *P.P.*, p. 75.

[8] *P.P.*, pp. 27–28. I have retained the spelling of the original text in all the quotations, but have modernized the rather chaotic punctuation.

WOE TO HIM WHO TOUCHES WOMAN

A farmer found a faun shivering in the winter's cold and brought him to his own hearth and fireside. The mountain satyr had never beheld a fire: to his eyes it seemed beautiful and worthy of love. He had seen the sun; he saw that the fire was just like the sun — and what holds the universe more worthy of love than the sun? He thought — poor half-wild satyr! — that the sun had slipped into the house and onto the warm, glowing hearth. Straightway he wanted to embrace it and to kiss the flame. But the farmer held him back and thus upbraided him: "Stop! If you don't keep away, your beard will be burned, my shaggy fellow! And where you see beauty, you'll discover pain. View it from a distance: that will give you pleasure, but if you come close and touch it, you'll be hurt! Touch not! Instead, enjoy the view!"

The moral of our tale is this: Wanton young men, keep clear of the flames of beauteous Venus. She has a lovely form, but beneath it lies the poison that is woman: to behold is pleasure; to touch is pain.

To the same point is another poem which gives a perverted interpretation to the figure of the ivy and tree, so beloved by the ancients as the symbol of marital affection:

NOXIA COPULATIO

Enecat amplexu serpens hedera arboris altae
  Quo sustinetur stipitem.
Sic et amica procax hedera formosior alba,
  Lentis adhaerens bracchiis,
Quem semel amplexa est lascivo occidit amore,
  Suggens opes et sanguinem.[9]

A DEADLY UNION

With its embrace the creeping ivy slays the lofty tree by which it is supported. Even so a bold mistress, more lovely than the bright ivy, clings with her entwining arms, and once she has embraced a man, she kills him with her wanton lust and sucks away his wealth and lifeblood.

Again, a series of three pictures is run together and interpreted by an amusing set of verses entitled "*Mulier Umbra Viri.*" The first cut shows the sun casting the shadow of one man behind him and that of another in front of him; the second depicts Daphne pursued by Apollo and turning into a tree; the third pictures the story of Echo and Narcissus:

[9] *P.P.*, p. 56. The cut is of a tree entwined with an amorphous vine clearly intended to be ivy. Note in the last line the spelling "*suggens*" for "*sugens.*"

MULIER UMBRA VIRI

[First cut]

Umbra suum corpus radianti in lumine solis
Cum sequitur refugit, cum fugit insequitur.
Sic sunt Naturae tales muliebris Amores
Optet amans, nolunt; non velit, ultro volunt.

[Second cut]

Phoebum virgo fugit Daphne inviolata sequentem;

[Third cut]

Echo Narcissum dum fugit insequitur.
Ergo voluntati plerumque adversa repugnans
Foemina, iure sui dicitur umbra viri.[10]

WOMAN IS MAN'S SHADOW

The bright rays of the sun cast for every man his shadow: when he pursues it, it flees him; when he flees, it runs after him. Even so are the affections of woman: let her lover desire, she says him nay; let him be unwilling, she becomes all eagerness.

The maiden Daphne flees Apollo, who pursues her.

Narcissus runs away, and Echo follows after. And so woman, because she ever opposes his desire, is rightly called man's shadow.

There are others in a similar vein but even more drastic in their condemnation of womankind. One, appended to a cut illustrating the story of the discovery of the Panpipes, and entitled "*Amorum Conversio ad Studia,*" draws this moral:

Haec ab amoribus ad studia est conversio, cum quis
A scorto ad libros vertitur et calamos.
Est satyrus iuvenis scortator, arundo, Puella
Flexilis in quemvis (det modo dona) virum.

. . . . .

Fistula disparibus septem compacta cicutis
Iunctas septem artes denotat ingenuas.[11]

This is our reform from love to study, when a man turns from his mistress to his books and pens. The satyr is the love-bent young man, the reed is the girl — for she bends to any man, bring he but gifts . . . . The pipe, formed of seven unequal stems, depicts the seven joint and noble arts.

Again a picture of Hermaphroditus in the Salmacian fount tells us that a passion for women makes a man effeminate and "*semivir.*" [12]

[10] *P.P.*, pp. 61–62.
[11] *P.P.*, pp. 17–18, vv. 11–14, 19–20. Note in v. 12 the neat pun on "*calami.*"
[12] *P.P.*, p. 33.

Finally, a cut of Medea killing her children leads to the conclusion:

> O sexus cupiens vindictae ac viribus impos,
> Hyrcana mulier Tigride saeva magis! [13]

O sex lustful for vengeance and of passion uncontrolled, woman, more savage than the Hyrcanian tigress!

Perhaps not too far from these suspicions of women lies the source of Aneau's strictures against two further common predilections of the young student, athletic sports and dancing. His verses on the former are intended to interpret a cut showing two young men at a game of tennis; one of them has just struck the ball with his racket; the other is poised for a return "drive":

MAGNUS LABOR CASSUS

> Exercet partes pila sphaerica corporis omnes,
> Ora, manus, oculos, brachia, crura, pedes.
> Quique pila ludit motus incompositos dat,
> Corporis affectus concipit et varios.
> Nam modo laetitia gestit, modo rumpitur ira;
> Flet, ridet, dubium spesque metusque tenent.
> Denique non agit, at satagit conamine multo,
> Idque pilam circa, rem minimi precii.
> Scilicet ex membris tanto sudore solutis
> Ut nullum existens inde supersit opus.
> Sic faciunt (aliter quam vult Prudentia) qui dant
> Difficiles operas rebus inutilibus.[14]

MUCH ADO ABOUT NOTHING

The round ball exercises every part of the body, the face, the hands, the eyes, the arms, the legs, the feet. And he who plays at ball makes graceless motions and twists his body into many a varied pose. For now he shouts with joy, and now he bursts with wrath; he weeps, he laughs, as hope and fear pull him this way and that. Finally, with mighty effort he does not exert but over-exerts himself — and this for a ball, a thing of little worth. Hence it comes about, of course, that his sweaty, weary limbs have no strength left for other things. Even so men do, who, against the dictates of prudence, give toilsome effort to useless things.

I fear, then, that Aneau would have been no zealous supporter of extracurricular activities, for he feels that games and such diversions tire the youth and leave him no energy for more important things. Besides that, they lead him to emotional extremes, and, worst of all, destroy his masculine dignity. It is this last fault that causes Aneau

[13] *P.P.*, p. 76, vv. 9–10. [14] *P.P.*, p. 78.

to inveigh against dancing. Beneath a picture of a monkey dancing to the music of the viol and lute for the benefit of a group of young men and women, Aneau declares that a man who dances is just as ridiculous as a monkey; anyone ignorant of this custom who chanced to see him would judge him insane:

Dat motus incompositos, numero meditatur
Respondere pari, conveniente pede;
Dum studet ac uni stultae placuisse puellae
Ridendum se aliis omnibus exhibuit,
Siquis ut ignarus sit consuetudinis huius,
Insanire putet quem videt hoc agere.[15]

His motions are graceless as he strives to keep his foot in time with the measure, and while he attempts to please one silly girl alone, he makes of himself a fool in all other men's eyes. Why! were a man ignorant of this habit of ours, he would think one crazy whom he beheld thus carrying on!

For the arts of teaching and of training the young Aneau has a word, too. In verses that have a modern ring he attacks the "tyranny of teachers" and its harsh effect upon young students. The picture in this case shows Juno turning Callisto into a she-bear:

SCHOLASTICA GENEROSORUM CORRUPTELA

En dea saeva nimis fastu cultuque superbo,
Quae famulam manibus imperiosa ferit.
Ad cuius prostrata pedes mutatur in ursam
Virgo, cui fuerat libera forma prius.
Picta Magistrorum tali est eicone Tyrannis
Quae puerum Naturam efferat ingenuam,
Liberiore prius fuerant ut qui indole nati
Supprimat abiectos, cogat et esse feros.[16]

EVIL SCHOOLS CORRUPT GOOD MANNERS

Behold this goddess all too cruel, of pride and of haughty port, who in imperious wise strikes her slave girl with her hand. Lying prostrate at her feet, the maiden is being turned into a she-bear — a maiden whose form was noble ere this. Depicted in this image is the tyranny of schoolmasters, which makes savage the noble nature of their pupils. Yea, those whose nature until now was free and fine are cast down and oppressed, and willy-nilly turn into wild beasts.

The *Picta Poesis* reveals no very startling political doctrines. Aneau was apparently much too wrapped up in his teaching and writing to be greatly concerned with questions of public policy. However, in verses appended to a cut representing the metamorphosis

[15] *P.P.*, p. 106, vv. 9–14. Note the awkward order in v. 13 for "*ut siquis sit.*"
[16] *P.P.*, p. 32.

of the crew of Dionysus he describes in miniature the ideal state, which should be an oligarchy run by the best men in the interests of all; in one distich he seems to hint at the doctrine of the separation of Church and State — doubtless a rather bold political heresy for his day:

Namque Deum in summo residentem Ecclesia placat,
At proceres urbem pro ratione regunt.[17]

For the Church makes prayer to God on high, but the nobles in the name of reason rule the State.

In other verses the art of beekeeping serves to illustrate a whimsical theory of social altruism. This rather graceful poem is divided into two sections of six distichs each and ends in a distich which sums up the whole. The lines are not without humor and wit and an occasional sly bit of irony, and the way in which the poet turns the laugh on himself at the end reminds one of some of Horace's poems.

NON NOBIS NATI

Mel homo cum caera rapit ex alvearibus ipsis
In disco, longi fertque laboris opus.
Mel homini, ceramque Diis alvearia fingunt:
Sic vos non vobis mellificatis, apes.
Non sibi sed domino serit et metit arva colonus:
Sic vos non vobis mellificatis, apes.
Non sibi sed domino premit ustam vinitor uvam:
Sic vos non vobis mellificatis, apes.
Non sibi sed domino carpit sator arbore fructus:
Sic vos non vobis mellificatis, apes.
Non sibi patronus sed novit iura clienti:
Sic vos non vobis mellificatis, apes.
Non sibi sed regi miles gerit arma; tamen si
Occidit in bellis, occidit ipse sibi.
Nec sibi (cum superat) vincit: pro principe vincit:
Sic vos non vobis mellificatis, apes.
Non sibi praescribunt Medici sumenda, sed a[e]gris:
Sic vos non vobis mellificatis, apes.
Non sibi sed populo cantant sua carmina vates:
Sic vos non vobis mellificatis, apes.
Non sibi docti homines scribunt sed posteritati:
Sic vos non vobis mellificatis, apes.
Non sibi sed cunctis opifex sua in arte laborat:
Sic vos non vobis mellificatis, apes.
Ad nullos minus ac autores pervenit acti
Fructus: vivit, agit denique nemo sibi.[18]

[17] *P.P.*, p. 100, vv. 9–10.

[18] *P.P.*, pp. 101–102. In v. 17 the text gives "*agris*," an obvious error for "*aegris*."

ALTRUISM

Man takes the honey and the wax from the very hives, and in a dish bears off the fruit of long toil.

The hives make honey for man and wax for the gods: even so not for yourselves do you make honey, O bees.

Not for himself but for his lord the peasant sows and reaps: even so, etc.

Not for himself but for his lord the vintner presses the ripe grape: even so, etc.

Not for himself but for his lord the planter picks fruit from the trees: even so, etc.

Not for himself does the lawyer know the law, but for his client: even so, etc.

Not for himself but for his king does the soldier bear arms; yet if he dies in the wars, that is his own concern.

Nor — if he lives — does he conquer for himself: he conquers for his prince: even so, etc.

Not for themselves do doctors prescribe remedies, but for the ill: even so, etc.

Not for themselves but for the public do the poets sing their songs: even so, etc.

Not for themselves do the learned write their tomes, but for generations to come: even so, etc.

Not for himself but for all men does the artist toil at his art: even so, etc.

But to no men comes less return from their work than to authors: yea, no man lives or toils for his own sake.

The picture of the busy farmers who toil not for themselves but for their lords has a social significance too clear to be missed, especially when we recall that the comparison is with the bees and those who steal their honeycombs. Here is an implied stricture against the social and economic order which would have made the author suspect in days other than the remote sixteenth century! Besides that, the verses on the soldier, who conquers "for his prince" but whose death is his own concern, hint at pacifistic doctrine of the sort that lies behind Remarque's *All Quiet on the Western Front*, and similar books of the period since 1918.

Against his own countrymen Aneau directs a witty satirical epigram based on a punning use of the word *gallus*. The poem is attached to a cut showing a cockfight.

ΑΛΕΚΤΡΥΟΜΑΧΙΑ

In volucres aquilae, in vulturiosve rapaces
    Diversae aut alias conditionis aves,
Cristati nunquam committunt praelia galli,
    Pro praeda aut generis nobilitate sui.
At pro Gallinis victoriae amore salaces
    In Gallos Galli bella cruenta movent.
In genus atque suum sunt acres, caetera molles.
    Solo utinam similes nomine, Gens et avis! [19]

[19] *P.P.*, p. 64.

THE COCKFIGHT

Against fowl or against greedy vultures the eagle directs his attack, or against other birds, of different sort from his own; but crested cocks never fight for booty or in defense of the good name of their kind. They battle over hens: love of victory in such battle gives them zeal, and bloody war they wage, cock against cock. Against their own kind they are warriors bold; to all others they are cowards. Ah, would that only in name were they alike, the people and the bird!

These few selections will, I believe, serve to illustrate the character of the whole book. A quaint little thing, it possesses an undeniable if indefinable charm, in spite of the fact that there is in it no small measure of triviality and pedantry. Its author, as Gerig says, "was not a poet of importance: he was merely one of the many clever versifiers, last offshoots of the dead rhetorical school." [20] Yet in a day when rhetoric is dead and wit a lost art, these poems of Aneau's have a tantalizing sparkle. They take us back to the time when cultivated men wrote for the joy of seeing what they could do in verse with some set theme. And they did not always write trivialities; occasionally — perhaps by accident — they expressed a striking thought which may still lay claim to our attention and consideration.

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[20] *Romanic Review*, 1 (1910): 181.

SOME NOTES ON THE OTTAWA DIALECT

HIRSCH HOOTKINS

FOR this opportunity of discussing the Ottawa dialect I am indebted to Dr. C. F. Voegelin, of Depauw University, who introduced me to the field of Algonquian studies, and to Dr. W. B. Hinsdale, Mr. W. Vernon Kinietz, and Dr. Emerson F. Greenman, of the University of Michigan. Dr. Hinsdale discovered an Ottawa Indian family living in Ann Arbor, and Mr. Kinietz and Dr. Greenman enabled me to interview them.

In December, 1939, I went to see Mrs. Cecilia Knox (née *sɛ·zi·'n šɛgani·'bi*) and her brother George (*sa·'bu·*, as he is known in Ottawa). Most of what I have learned since is due to the patience and kindness of Mrs. Knox, although her brother has been of assistance, especially in rechecking my material.

I soon found that my informants could give me satisfactory answers to any questions put to them, but were unable to dictate a text. I therefore decided to investigate the phonetic pattern of the language and to lay the groundwork for a grammatical and linguistic study to be undertaken later.

As spoken by my informants, Ottawa possesses the following sounds and phonemes:

1. Oral Vowels (*a, ɛ, i, ɔ, u, o, ə; a·, ɛ·, i·, ɔ·, u·*):
   - (*a*) Like the a in 'car'; often, in rapid speech, tends to be pronounced as the a in 'ball.' Phonemically it is better to write (*a*) in all cases.
   - (*ɛ*) Somewhat closer than the English e in 'met.'
   - (*i*) Like the i in 'pin.'
   - (*ɔ*) Like the first o in 'coroner,' but somewhat closer and more rounded.
   - (*u*) Like the u in 'put.'
   - (*o*) A rare sound, like the o in 'poet.'
   - (*ə*) The schwa, a neutral sound which is of diverse timbres. Further study may show that it is a very weak (*a*) before (*n, w*) and a weak (*i*) before (*m*) and in word-final position.
   - (*a·*) A longer, closer variety of (*a*), like the a in 'father,' often heard as ou in 'bought,' especially in rapid speech. Phonemically all these sounds should be written (*a·*).
   - (*i·*) A long, close vowel like the i in 'machine.'
   - (*ɛ·, ɔ·*) Lengthened (*ɛ, ɔ*).
   - (*u·*) A long, very close sound, somewhat more rounded than the u of 'rude.'

2. Nasal Vowels (*ã, ɛ̃, ĩ, ɔ̃, ũ*):
   - (*ã*) Closer than the corresponding oral vowel.
   - (*ɛ̃*) Slightly more open than (*ɛ*).
   - (*ĩ*) A very open nasal (*i*) tending toward (*ɛ̃*), a very close nasal (*ɛ*). Often it is difficult to decide which to write, since it is derived etymologically from both (*in*) and (*ɛn*).
   - (*ɔ̃, ũ*) Nasal varieties of (*ɔ, u*), but slightly closer.

These vowels resemble closely the French nasal vowels, i.e. they are pure nasals. They are short, except before (*s*), when they are always long. Phonemically there is no reason to indicate this longer variety.

3. Consonants:
   - (*w, y, ỹ*)
     - (*w*) A voiced consonant, like the English **w** in 'went.'
     - (*y*) A voiced sound, like the English **y** in 'young.' It occurs mostly as a glide between vowels and very often is quite weak.
     - (*ỹ*) A peculiar nasal variety of (*y*), which occurs only as a glide before (*a·*), the ending of the first person singular of the dependent mode.
   - (*m, n, ŋ*)
     - (*m, n*) Voiced nasal continuants, like the English **m** and **n** in 'many.'
     - (*ŋ*) A velar nasal continuant, like the **ng** in 'sing'; occurs only before *k* and in word-final position, derived from original (*ŋk*). In composition the original *k* reappears.
   - (*p, t, k*) Lenis stops, slightly voiced in intervocalic position and before the voiced consonants; voiced after the homorganic nasals (*m, n, ŋ*), respectively. After (*–u–*) the (*–k*) seems to have a labialized release. As first member of a cluster they are released.
   - (*p̈, ẗ, k̈*) Fortis stops, slightly lengthened. Their presence is shown in intervocalic position by the fact that voicing does not take place.
   - (*s, š*) Lenis continuants ((*š*), like **sh** in 'short'). Voiced under the same conditions as the stops.
   - (*s·, š·*) Fortis continuants, much longer than the corresponding lenis sounds.
   - (*č, č·*) Lenis and fortis affricates, like the **ch** in 'church'; the second is lengthened, the stop on-glide being the part lengthened rather than the sibilant off-glide. The lenis member undergoes voicing intervocalically and before voiced consonants.
   - (*ˀ*) Glottal constriction, not a full stop; so far found only before (*w, m, ŋ*), and perhaps (*kw*).

It should be noted that fortis consonants occur only intervocalically and are ambisyllabic. The slight voicing of consonants depends upon the speed of utterance; the faster the speech, the more likely the consonants are to be voiced.

The language is very rich in clusters. In all, seventy-one have been noted, divided according to the initial consonant as follows: *k*, 7; *t*, 4; *p*, 8 (2 of 3 consonants); *s*, 5 (1 of 3); *š*, 8 (2 of 3); *č*, 4; *m*, 12 (4 of 3, 1 of 4); *n*, 18 (8 of 3, 1 of 4); *w*, 2; *ˀ*, 3.

The word, whose utterance begins clearly and strongly, tends to lose strength as it progresses and ends in an indistinct or murmured syllable. As a result of this condition:

1. A final (*–kwi*) or (*–kwa*) sounds very much like a weak (*–gu*).
2. Final (*–k*) and (*–t*) are indistinguishable.
3. A final vowel followed by *n* is often heard as a nasal vowel, and vice versa.
4. An original final (*–i*) may appear to be (*–ɛ*).

The short unaccented vowel of the original Algonquian initial syllable [1] has, with few exceptions, disappeared in Ottawa. In absolute initial position this vowel is restored after a personal prefix ending in (*–t–*). This law also affects the vowel of the prefix, including the (*u–*) or (*o–*) of the third person. Examples:

ki'ma·, 'king'	*mši'mnitu·*, 'devil'
tu'kima·n, 'his king'	*špimiŋ*, 'heaven'
ntu'kima·, 'my king'	*mka·'kan*, 'boxes'
ki'ma·k, 'kings'	*mka'smun*, 'tent'
pku·'čku·ku·š, 'wild hog'	*mki's·in*, 'shoe'
kči'si·pi, 'big river'	*mki'snan*, 'shoes'
kči'si·pin, 'big rivers'	*mkwɔ·'*, 'bear'
tku·'si, 'short'	*mskwa·'*, 'red'
pkɛ's·an, 'peach'	*naŋk*, 'star'
pkwači'pšɛkɛ, 'buffalo'	*naŋ'ku·k*, 'stars'
mni'tu·, 'spirit'	

In rapid speech *nmki's·in*, 'my shoe,' heard as *mki's·in*, differs in no way from *mki's·in*, 'his shoe.' In a word with initial *k–*, like *kči'si·pi*, the three possessors are scarcely to be distinguished. As a result, for purposes of clarity or emphasis, the absolute forms of the personal pronouns may be prefixed to the possessed noun forms:

ni·ŋkči'si·pi	*ki·ŋkči'si·pi*	*wi·ŋkči'si·pi*, etc.
ni·npkɛ's·an	*ki·ŋkpkɛs·an*	*wi·npkɛ's·an*, etc.

The same phenomenon appears in the verb.

The possessed noun has the following affixes:

ANIMATE

SINGULAR	PLURAL
n–	*n–* . . . . . *–ak*
k–	*k–* . . . . . *–ak*
– . . . . . *an*	– . . . . . *–an*
n– / *k–* } . . . . *(a)na*	*n–* / *k–* } . . . . *–(a)na·'nak*
k– . . . . . *(a)wa*	*k–* . . . . . *–(a)wak*
– . . . . . *(a)wan*	– . . . . . *–(a)wan*

[1] Jones, William, "Algonquian (Fox)" in *Handbook of American Indian Languages*, Bureau of American Ethnology, Bull. 40, Part I, sec. 16, pp. 763–793.

The inanimate has no obviative forms; its plural suffix is *–an*.

The diminutive is formed by suffixing *–s* to a nasal vowel; i.e. –Ṽ*s*: *mni'tũ·s*.

The augmentative is formed by the prefix *kči'–*.

The particle *apči'–* adds a superlative tinge to the word to which it is prefixed.

The animate intransitive verb has the following prefixes and endings:

		Independent	Dependent
Singular	1.	*ŋ–* ..... –	..... *–a·*
	2.	*k–* ..... –	..... *–an*
	3.	– ..... – (or *na'ki·*)	..... *–Vt*, *–Ck* (i.e. *ŋ*)
	Obv.	– ..... *–n*	..... *–nit*
Plural	1.	*n–* ..... *–mɛ* (exclusive)	..... *–iŋ*
		k– ..... *–mɛ* (inclusive)	..... *–aŋ*
	2.	*k–* ..... *–m*	..... *–ɛ·k*
	3.	– ..... *–wak*	..... *–wat*
	Obv.	– ..... *–n*	..... *–nit*

The syllable *wi·–* prefixed to the stem forms a kind of immediate future; *ki·–*, a past.

The numerals are:

1, *pɛ·'ši·k*	8, *swa·'swɛ*	30, *si'mtana*
2, *ni·'š*	9, *ša·'ŋkswɛ*	40, *ni·'mtana*
3, *swɛ*	10, *mta·'swɛ*	50, *na·nmi't(a)na* or *na·'mtana*
4, *ni·'win*	11, *mta·'swɛ ši·pɛ·'ši·k*	80, *šwa·'smit(a)na*
5, *na·'nan*	12, *mta·'swɛ ši·ni·'š*	100, *ku'twak*
6, *kutwa·'swɛ*	13, *mta·'swɛ ši·'nswɛ*	1,000, *mta·'swak*
7, *ni·šwa·'swɛ*	20, *ni·'štana*	

In composition, as first element, 'one' is *ku–* or *kut–*.

The material collected thus far leads me to believe that Ottawa is very closely related to Chippewa, so closely that I am tempted to regard them as dialects of one language.

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MIDDLE ENGLISH *ŏ* IN AMERICAN ENGLISH OF THE GREAT LAKES AREA

ALBERT H. MARCKWARDT

IT IS generally supposed that in stressed syllables Middle English *ŏ* was a back rounded vowel.[1] After the beginning of the fifteenth century naïve spellings of this vowel with the letter *a* are found with increasing frequency. On the basis of such spellings it is assumed that there was at this time a tendency to unround ME *ŏ* to a sound approximating [ɑ].[2] This assumption is fortified by occasional rhymes such as *plot* : *that* and *stormes* : *harmes* : *armes* in Spenser, and *dally* : *folly* in Shakespeare, and by certain of the early orthoëpists, who identified the sound of English *ŏ* with that of French *ă*.[3] In the seventeenth century the unround vowel seems to have been a fashionable pronunciation. Evidence for this is found in Vanbrugh's *The Relapse*, where Lord Foppington's oft repeated "stap my vitals" is accompanied by such spellings as *Tam, Gad, bax, fand, praper, resalve,* etc.[4]

Today the development of ME *ŏ* has come to be one of the differentiae of American speech. Standard British English generally has here the low back rounded vowel [ɒ], e.g. [stɒp, nɒt, fɒg].[5] In America pronunciation ranges from the mid-central unround vowel

[1] Wyld, H. C., *A Short History of English* (New York: E. P. Dutton and Co., 1927), p. 81; Jespersen, O., *A Modern English Grammar* (Heidelberg: Winter, 1928), I, 90; Davies, C., *English Pronunciation from the Fifteenth to the Eighteenth Century* (New York: E. P. Dutton and Co., 1934), p. 3.

[2] Kihlbom, A., *A Contribution to the Study of Fifteenth Century English* (Uppsala: Lundequist, 1926), pp. 142–145; Wyld, H. C., *A History of Modern Colloquial English* (New York: E. P. Dutton and Co., 1937), p. 240.

[3] Included here are: Bellot, *The French Methode*, 1588; *L'Alphabet anglois*, 1625; Mauger, *Grammaire angloise*, 1679.

[4] Nor was Vanbrugh the only Restoration dramatist to employ such spellings. I have noted *Tatnam* (Tottenham), *warld, carking* in Wycherley's *Gentleman Dancing Master*.

[5] The unround vowel [ɑ] for ME *ŏ* is common, however, in several of the present British English dialects, especially in Devon, Dorset, Wiltshire, Sussex, Kent, and less frequently in the South Midlands and in parts of Scotland. See J. Wright, *The English Dialect Grammar* (Oxford: H. Frowde, 1905), pp. 72–74.

[ɑ] to the higher low-back rounded [ɔ]. Students of American English often comment that perhaps there is no other one class of words in which our pronunciation varies so much. New England differs from the South, and both these regions are unlike General American. Nor can we even assume for all portions of the General American area a uniform development of ME *ŏ*.[6]

In spite of such divergence, discussions of ME *ŏ* in American English are often confined to generalities. It is usually conceded that the behavior of this vowel is dependent upon phonetic environment, but the few attempts to describe the variations in pronunciation throughout any one of the three American speech areas have all been somewhat vague. In particular, there has been little detailed analysis of the situation in General American except for Robertson's statement that "the [ɑ] changes to [ɔ] as one goes west from the Middle Atlantic seaboard, the alteration beginning in western Pennsylvania."[7] After examining the sketchy treatments of the subject one is forced to conclude with Luick that "Das Schwanken zwischen [ɑ] und [ɔ] in Amerika bedarf noch näherer Untersuchung."[8]

Data for a more detailed description of the status of ME *ŏ* in at least a part of the General American speech area are at hand in the field records collected by the Survey of Folk Speech in the Great Lakes Area and the Ohio River Valley, a project which has been supported by the Horace H. Rackham Foundation at the University of Michigan. At present thirty-five field records have been made in as many different communities: eight each from the states of Michigan and Indiana, nine from Ohio, and ten from Illinois. Each of these records is a close phonetic transcription of the replies of a single

[6] For treatments of ME *ŏ* in American English see: Grandgent, C. H., "From Franklin to Lowell," *PMLA*, 14 (1899): 218–220; Krapp, G. P., *The Pronunciation of Standard English in America* (New York: Oxford University Press, 1919), pp. 57–59; Krapp, G. P., *The English Language in America* (New York: The Century Co., 1925), I, 141–148; Kurath, H., *American Pronunciation*, S.P.E. Tract No. XXX (Oxford: At the Clarendon Press, 1928), pp. 285, 287, 289, 294; *Webster's New International Dictionary*, Second Edition (Springfield: G. and C. Merriam Co., 1934), p. xlviii; Kenyon, J. S., *American Pronunciation* (Ann Arbor: G. Wahr, 1935), pp. 179–185; Kennedy, A. G., *Current English* (Boston: Ginn and Co., 1935), p. 169; Robertson, S., *The Development of Modern English* (New York: Prentice-Hall, 1934), pp. 239–240.

[7] Robertson, *loc. cit.*

[8] Luick, K., *Historische Grammatik der englischen Sprache* (Leipzig: Tauchnitz, 1929), I, 714, Anm. 3. Both Luick and Robertson, in the statements quoted, assign to the symbol ɔ the value which I give to ɒ in this paper.

informant to approximately 550 questions which have been designed to reveal those characteristics of American English which vary from one region to another.[9]

Some explanation of the choice of communities and of the type of informant is also apropos. The history of the settlement of these states was carefully analyzed in respect to the place of origin of the early settlers, subsequent movements of American-born groups into and through the region, and changes in population during the last four decades. Each community which, after such analysis, was finally selected as a locale for a field record was felt to be representative of a somewhat larger speech area. For example, Delavan in Tazewell County, Illinois, was chosen to represent the influx of Rhode Islanders in particular and New Englanders in general into that section of the state.

For a number of reasons which need not be explained here the staff of the Survey of Folk Speech was interested in securing samples of the oldest stratum of native speech indigenous to the community. Accordingly, the informant selected from each of these communities was at least seventy years old, had been born of English-speaking parents in or about that community, had not lived outside it for any length of time, and had had only a common-school education or less. Although the pronunciation of these older informants may differ in certain respects from that of the younger and more highly educated generations, it will be granted, at least, that we are here concerned only with comparing members of the same genus, and, moreover, that we are dealing with as genuine a *Volkssprache* as one may hope to secure in a country characterized by mobile population, widespread education, and indistinct lines of social stratification.

The work sheets of the Survey of Folk Speech are designed to secure the pronunciation of forty-nine words with ME ŏ as their stressed vowel. For the sake of convenience these forty-nine words, listed below, have been roughly classified on a phonetic basis. The first group (I) is composed of monosyllables, the second (II), of plurisyllables. The divisions within the groups are according to the nature of the consonant following the stressed vowel: In (*a*) this

[9] The fieldworkers participating in this survey were: Professor Norman Eliason, of the University of Florida, Dr. Frederic G. Cassidy, of the University of Wisconsin, and Mr. Harold B. Allen, of the University of Michigan. Four of the Ohio records were contributed through the kindness of Professor Hans Kurath, director of the *Linguistic Atlas of the United States and Canada*.

consonant is a voiceless fricative, in (*b*) it is [r], in (*c*) a nasal or voiced continuant, in (*d*) a voiced stop, and in (*e*) a voiceless stop. The words are:

I. Monosyllables

(*a*) cough, loft, off, cost, frost, moth [10]

(*b*) cork, corn, horse, storm

(*c*) on, long, strong [11]

(*d*) God (reverent), God (profane), hod, dog, fog, frog, hog, log

(*e*) crop, slop, strop, lot, pot, cock, dock, ox, rock, shock

II. Plurisyllables

(*a*) coffee, coffin, office, often, hospital

(*b*) borrow, dornick, forehead, morning, oranges, orphan, tomorrow

(*c*) vomit, college, closet

(*d*) foggy

(*e*) stopper, cottage, pocket

In the remainder of this paper each of these groups will be considered in turn, to show in what portions of the surveyed area rounded vowels of the [ɒ] type are prevalent and where unround vowels of the [ɑ] type occur.[12]

(*a*) ME *ŏ* before the voiceless fricatives [f], [s], [θ]. — In mono-

[10] The inclusion of *moth* could be challenged on the ground that the [ɔ] could have developed from OE *mohðe*, which would have become ME [mɔʊxθə] and hence not subject to consideration as a pure instance of ME *ŏ*. Since this was the only word in the work sheets in which a possible ME *ŏ* is followed by [θ], it was included here anyway.

[11] *Long* and *strong* could have had a long vowel in ME as a result of lengthening by a homorganic consonant group in late OE. In many instances, however, the unlengthened vowel was maintained alongside the lengthened form throughout the ME period, and it is not wholly clear whether the MnE pronunciation represents the long or the short vowel.

[12] According to the system of transcription employed by our fieldworkers, four vowel symbols are likely to be used in transcribing the stressed vowels of these words. They are: ɑ, σ, ɒ, ɔ. The first two represent respectively the low central unround and the low back unround vowels. The third is a low back rounded vowel, and the last is also back rounded, somewhat higher and more round than ɒ, but less so than the mid-back o. Moreover, since the diacritic ̮ is also employed to indicate more than normal rounding, it is possible to show four degrees of rounding in the low back position, namely: σ (wholly unrounded), σ̮ (slightly rounded), ɒ (normal rounding), ɒ̮ (more than normal rounding). In the discussion which follows, the term *unround* refers only to [ɑ] and [σ]; *round*, to any one of the transcriptions [ɑ̮], [σ̮], [ɒ], [ɒ̮], [ɔ], [ɔ̮].

syllables some rounded vowel occurs regularly throughout the whole area before any of the three voiceless fricatives.[13] In plurisyllables the rounded pronunciation is also heard regularly before [f]. In *hospital*, however, the one plurisyllable in our work sheets which furnishes an instance of ME ŏ before [s], the situation is wholly different; the unround vowel is found in approximately two thirds of our territory, as illustrated in Figure 1.

In connection with the quality of the rounded vowel in this whole group of words one other observation must be made. The field records show a lower and more open vowel in the northern part of this area than in the southern. To illustrate, the vowel of *frost* was generally transcribed in Michigan by some modification of the symbol [ɒ], the lowest of the back vowels; in Ohio, Indiana, and Illinois some modification of [ɔ] was regularly employed by the field-workers.[14]

(*b*) ME ŏ before [r]. — In monosyllables, the rounded vowel occurs regularly throughout the whole area.[15] This was also true of the plurisyllables *morning* and *orphan*. Except for five scattered instances of unround vowels, *forehead* and *orange* are regularly rounded, as is also the dialect word *dornick*, 'a small stone,' when the *r* is pronounced (when the *r* is not pronounced it is regularly [dɑnɪk]). The words *borrow* and *tomorrow* behave totally unlike the others in this group in that they appear with an unround vowel a little more frequently than with a rounded vowel. Fourteen informants used a variety of [ɑ] in both words, eleven used a rounded vowel in both, and ten used [ɑ] in one and [ɒ] or [ɔ] in the other. As may be seen from Figure 2, Ohio appears to favor the rounded vowels, whereas the unround variety prevails in Michigan and Illinois, but there are no clear lines of cleavage.

[13] Our records show three instances of the unround vowel before a voiceless fricative in monosyllables: one of [frɑst] in northern Michigan, a similar pronunciation of *loft* in central Michigan, and one of *cough* in central Ohio. This is, of course, wholly negligible when compared with 195 instances where the rounded vowel was used, yet it is significant that two of these unround pronunciations were found in Michigan. Two instances of [ɑ] were also recorded for the plurisyllable *coffee* in central Indiana, although one of the informants had an alternate pronunciation with the rounded vowel.

[14] This is particularly significant, since Michigan and Illinois were covered by the same fieldworker, Mr. Allen.

[15] There was just one exception to this: a single pronunciation of *cork* with the vowel [ɑ˂] in southern Ohio.

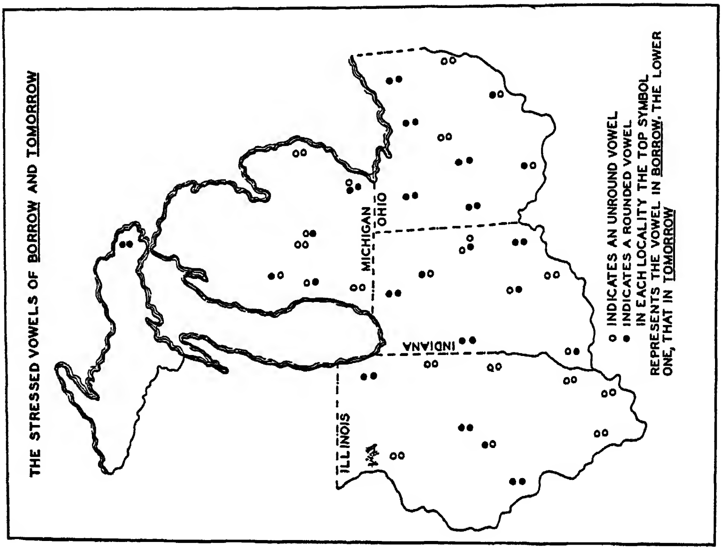
THE STRESSED VOWELS OF BORROW AND TOMORROW
MICHIGAN
OHIO
INDIANA
ILLINOIS
o INDICATES AN UNROUND VOWEL
• INDICATES A ROUNDED VOWEL
IN EACH LOCALITY THE TOP SYMBOL
REPRESENTS THE VOWEL IN BORROW, THE LOWER
ONE, THAT IN TOMORROW

FIG. 2

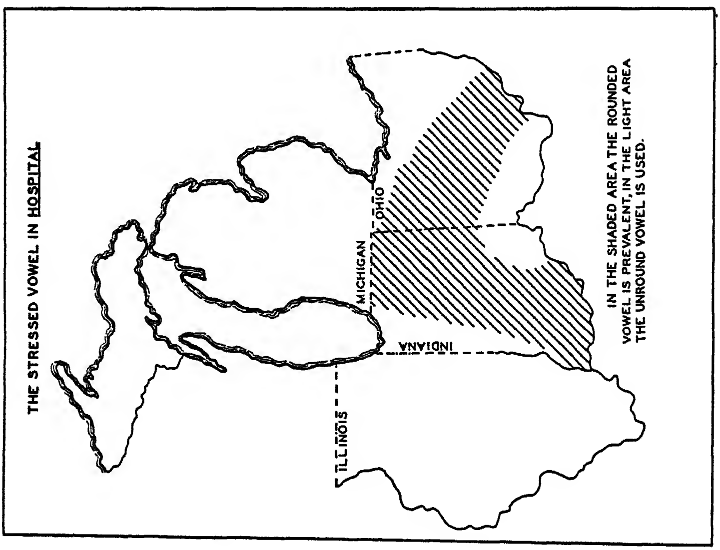
THE STRESSED VOWEL IN HOSPITAL
MICHIGAN
OHIO
INDIANA
ILLINOIS
IN THE SHADED AREA THE ROUNDED
VOWEL IS PREVALENT, IN THE LIGHT AREA
THE UNROUND VOWEL IS USED.

FIG. 1

So far as I know, the behavior of these two words in General American has not been pointed out before. Kenyon, in his treatment of the topic, includes *tomorrow* with such words as *orange* and *foreign* in his comment that [ɔ] is the "prevailing General American natural pronunciation." [16] Casual observation has convinced me that in the Great Lakes area the words *sorrow*, *hollow*, and *follow* are to be classed with *borrow* and *tomorrow*. Although it is not the purpose of this paper to inquire into the causes of these developments, it should be noted that in both *borrow* and *-morrow* the stressed vowel is preceded by a labial consonant, a phonetic environment usually conducive to rounding or to the retention of a rounded vowel. Moreover, the word *morning*, also with a labial before the stressed vowel, is rounded throughout our entire area. Since we find that such words as *borrow*, *follow*, *tomorrow*, and *sorrow* behave in a manner quite different from other polysyllables in which the vowel is followed by [r], we can scarcely escape the conclusion that the final unstressed [o], common to all these words, has something to do with the development of the stressed vowel, that some kind of dissimilation has probably taken place.

As with the words considered in the preceding section, the Michigan informants tended to use a slightly lower vowel than those in the three states to the south.

(*c*) ME ŏ before nasals and voiced continuants. — Before the velar nasal [ŋ] the rounded vowel occurs regularly throughout this area, with occasional instances of unrounding in Michigan. The word *on*, in context demanding stress, was unrounded in Michigan, Illinois, and southern Indiana; weak rounding was found in northern Indiana, and a strongly rounded vowel in Ohio. In the plurisyllables *closet* was found to have a rounded vowel in Indiana and most of Ohio; Michigan and Illinois regularly have [ɑ].[17] In *vomit* and *college* the rounded vowel is limited to the sections of Ohio and Indiana indicated in Figure 3.

(*d*) ME ŏ before voiced stops. — Rounding is more extensive before [g] than before [d].[18] *Log* and *dog* are rounded throughout

[16] *Op. cit.*, p. 181.

[17] The distribution of round and unround vowels in *closet* is not very different from that in *hospital* as illustrated in Figure 1, except that the Western Reserve, along with the wide belt extending diagonally across Ohio from southeast to northwest, was found to use the rounded vowel in *closet*.

[18] Unfortunately our work sheets give us no test words containing ME ŏ before [b].

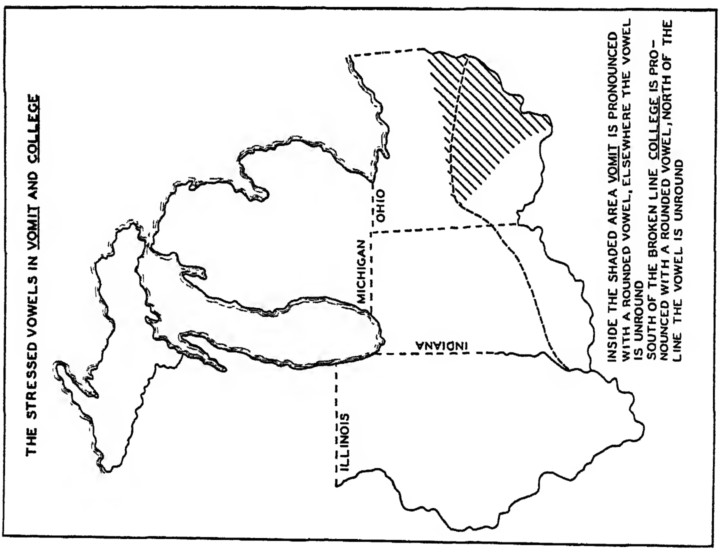
THE STRESSED VOWELS IN VOMIT AND COLLEGE
ILLINOIS
MICHIGAN
OHIO
INDIANA
INSIDE THE SHADED AREA VOMIT IS PRONOUNCED WITH A ROUNDED VOWEL, ELSEWHERE THE VOWEL IS UNROUND
SOUTH OF THE BROKEN LINE COLLEGE IS PRONOUNCED WITH A ROUNDED VOWEL, NORTH OF THE LINE THE VOWEL IS UNROUND

FIG. 3

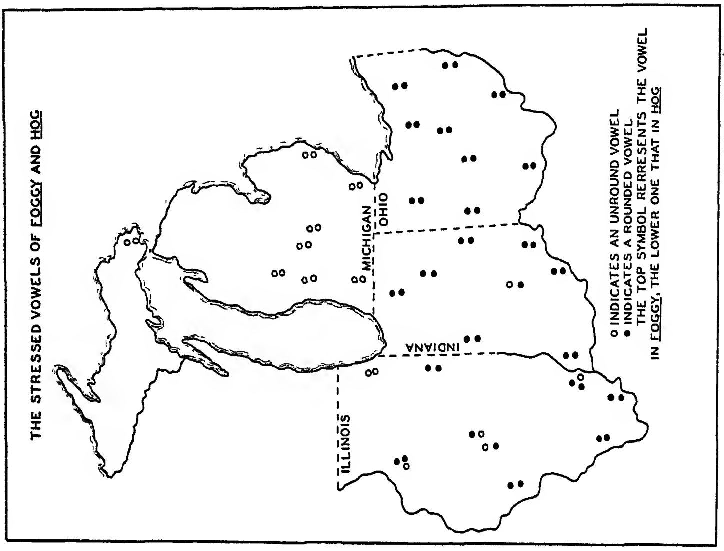
THE STRESSED VOWELS OF FOGGY AND HOG
ILLINOIS
MICHIGAN
OHIO
INDIANA
o INDICATES AN UNROUND VOWEL
• INDICATES A ROUNDED VOWEL
THE TOP SYMBOL RERRESENTS THE VOWEL IN FOGGY, THE LOWER ONE THAT IN HOG

FIG. 4

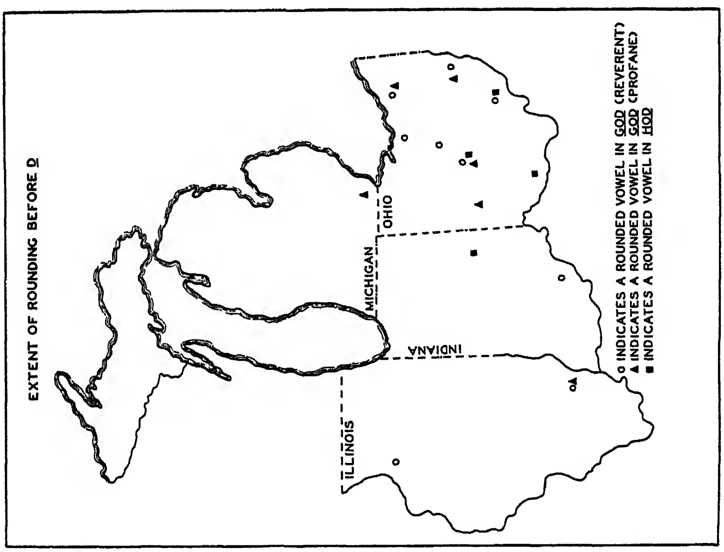
EXTENT OF ROUNDING BEFORE D
ILLINOIS
MICHIGAN
OHIO
INDIANA
o INDICATES A ROUNDED VOWEL IN GOD (REVERENT)
▲ INDICATES A ROUNDED VOWEL IN GOD (PROFANE)
■ INDICATES A ROUNDED VOWEL IN HOD

FIG. 5

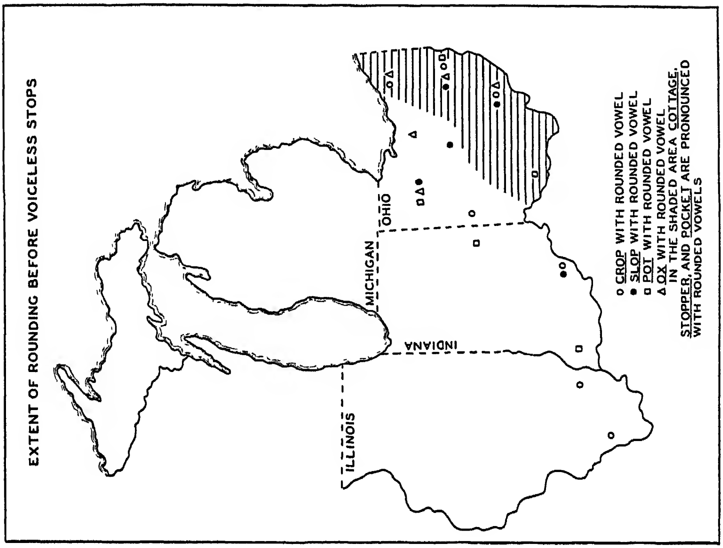
EXTENT OF ROUNDING BEFORE VOICELESS STOPS
ILLINOIS
MICHIGAN
OHIO
INDIANA
o CROP WITH ROUNDED VOWEL
• SLOP WITH ROUNDED VOWEL
□ POT WITH ROUNDED VOWEL
Δ OX WITH ROUNDED VOWEL
IN THE SHADED AREA COTTAGE,
STOPPER, AND POCKET ARE PRONOUNCED
WITH ROUNDED VOWELS

FIG. 6

the entire area. The distribution of *hog* and *foggy*, shown in Figure 4, is typical also of *fog* and *frog:* Michigan and northern Illinois employing the unround vowel, and rounding being prevalent in Indiana, Ohio, and southern Illinois. Figure 5 shows that rounding before [d] is common only in Ohio (though not in the northwestern part of that state).

(*e*) ME *ŏ* before voiceless stops. — Figure 6 indicates that rounding before [p], perhaps because of the labial environment, is distributed over a wider area than is rounding before [t] and before [k]. Note that the distribution of these forms does not differ greatly from that shown in Figure 5. The shaded area in Figure 6 shows also that rounding in plurisyllables is less extensive geographically than is rounding in monosyllables when a voiceless stop follows the vowel.

SUMMARY

Considered phonetically:

1. The rounded vowel occurs regularly before all the voiceless fricatives in monosyllables, before [f] in plurisyllables, before [r] (except for *borrow* and *tomorrow*), before [ŋ], and in some words before [g].

2. Rounding is somewhat less prevalent before [g] in certain other words, before [n], and before [s] and [z] in plurisyllables.

3. Rounding is still less in evidence before [d], and in monosyllables before voiceless stops. The fewest instances of rounding were found in plurisyllables before nasals, voiceless stops, and voiced continuants.

4. Given the same phonetic environment, rounding is usually less frequent in plurisyllables than in monosyllables.

Considered geographically:

1. In the area covered by this survey the rounded vowel is more common in Ohio than anywhere else. It occurs almost as frequently in the southern part of Indiana.

2. The unround vowel is chiefly characteristic of Michigan speech. The *frog, fog, hog* group, though rounded everywhere else, have the [ɑ] vowel in this state. Moreover, isolated pronunciations of [ɑ] in such words as *loft, frost, strong* occur in greater number here than in other portions of the area.

3. In words where the rounded vowel is found throughout the

entire area the vowel becomes higher and closer as one travels southward.

In conclusion, a few limitations of this study must be mentioned. First: since we are dealing here with only a single age group, it is impossible to determine the current trend in respect to the development of ME *ŏ*. We do not know if rounding is on the increase or the decrease, nor can we tell if this area or any part of it is at present the scene of conflicting tendencies. Second: a historical interpretation of these findings is impossible at present and will remain so until all the material of the New England atlas and of similar surveys in the South and Middle Atlantic states is available.[19] Third: our findings in respect to the rounding or unrounding of ME *ŏ* should be compared with a similar analysis of ME *a* preceded by [w], as in *water*, *swallow*, *quality*, etc., and with words such as *laundry*, *gaunt*, and *sauce* derived from ME *au*, to give us a complete interpretation of the tendencies toward rounding or unrounding in our territory.

Irrespective of these limitations, the evidence which has been presented does indicate, first, that the speech characteristics in the so-called General American area are by no means so homogeneous as is often believed and asserted, and, secondly, that even a wide-meshed survey such as ours can be helpful in defining regional variations which have not hitherto been accorded the careful analysis that they obviously merit.

University of Michigan

[19] Note, however, that Chart 8 in H. Kurath, *Handbook of the Linguistic Geography of New England* (Providence: Brown University, 1939), p. 30, shows the unround vowel as in *rod* to be characteristic of western Connecticut, western Massachusetts, and the state of Vermont. When this is correlated with the history of the settlement of Michigan (chiefly from New York State, which was in turn settled from western New England) the predominance of the unround vowel in Michigan is understandable.

VARIANT [γ] IN THE AKLAN DIALECT OF BISAYAN

FRANK G. RYDER

THE Aklan dialect of the Bisayan group is one of the least familiar among the important tongues of the Philippine Islands.[1] Although its existence has been known for some time virtually no work has been done on its phonology or grammar, and it is not recognized in any of the older lists of languages and dialects except that of Beyer.[2] This is remarkable in view of the fact that it is spoken by a large proportion of the population of Capiz and also in view of the number of interesting phonological, morphological, and lexical features which it presents. The study of the dialect being made at the University of Michigan is under the direction of Professor Albert H. Marckwardt. I have secured all the Aklan forms for this paper from our informant, Mr. Alfredo Morales, who speaks Aklan. Comparative work on any scale would have been impossible without Professor H. H. Bartlett's remarkable collection of dictionaries of the Philippine languages, which he graciously allowed me to use.

The province of Capiz is on the island of Panay, and Aklan is spoken in its northwestern part, in eleven of its twenty-eight municipalities. The dialect has spread through the basin of the Aklan River, along the coast to the east as far as Batan and Altavas, and to the west as far up the coast as Ibajay. Contrary to the belief of Scheerer,[3] however, Aklan is *not* spoken in Navas and Burwanga, the centers of the northwestern part of Capiz. The dialect of this section

[1] For general orientation on the geography of the Philippine languages and dialects see H. H. Bartlett, "Vernacular Literature in the Philippines," *Michigan Alumnus Quarterly Review*, 13, No. 23 (Summer, 1936): 214–217.

[2] Beyer, H. O., *Population of the Philippine Islands in 1916*. Manila, 1917.

[3] It was through Professor Bartlett's help that I recently secured the only reference to a scientific discussion of the Aklan dialect, that of Otto Scheerer, "Über einen bemerkenswerten L-Stellvertreter im Dialekt von Aklan auf der Insel Panay," *Zeitschrift für Eingeborenen-Sprachen*, 11 (1920–21): 241–259. Since Scheerer's paper treats the same general theme as the present essay, I have taken account of his work throughout.

is quite different from Aklan, which extends only to the municipality of Ibajay. To the map of Aklan-speaking Capiz as given in Scheerer [4] should be added the municipalities of Numancia, between Macato and Calivo, Batan, on the opposite point of the bay from New Washington, and Balete, between Madalog and Altavas. Their location may best be checked in the *Atlas of the Philippine Islands*.[5] The population figures of the 1939 census give the Aklan municipalities a total of 154,980 inhabitants.

A lexical comparison immediately reveals Aklan as a member of the Bisayan group, one of the four or so most important language families of the Philippine Islands.[6] There are, however, several features which separate Aklan quite distinctly from the other principal dialects of Bisayan, such as Cebuan, Hiligainon or Panayana, and Samar-Leyte.[7] One of the most striking is the peculiar treatment of the *l*-sound of Bisayan, which is a sound of very complex history. In terms of the most complete system of correspondences set up for the "Austronesian" languages, that of Dempwolff,[8] Bisayan *l* may represent the *l*- or *ḷ*-group in any position, the *d′*-, *ḍ*- (RLD), and *g′*-groups in medial position. Aklan has treated this *l* uniformly, without any distinction as to its origin.[9] The change which affects the *l* in the Aklan dialect is extraordinary because it represents one of the rare instances in which the sound is divided according to its phonetic environment. The *l*-sounds as well as the *r*- and *d*-sounds of the Philippine languages are generally very unstable, but the variation usually either affects the entire sound or divides it according to position in the word, or it affects single words without established

[4] *Op. cit.*, p. 242.

[5] Treasury Department, U. S. Coast and Geodetic Survey, *Atlas of the Philippine Islands*. Washington: Government Printing Office, 1900.

[6] Lopez, C., *The Language Situation in the Philippine Islands*, pp. 1–6. Institute of Pacific Relations — Series of Papers on Philippine Progress. Manila, 1931.

[7] Unfortunately the names of these dialects are written so variously that almost every author has a different manner of designating. Only time will decide between such spellings as *Hiligainon* and *Hiligaina* or such variants as *Hiniraya* and *Haray-a*.

[8] Dempwolff, O., "Die L-, R- und D-Laute in austronesischen Sprachen," *Zeitschrift für Eingeborenen-Sprachen*, 20 (1924–25) : 19–50, 116–138, 223–238, 273–319.

[9] But Tagalog *l* is dropped in intervocalic position only if it is not from the RLD sound. See C. E. Conant, "Indonesian L in Philippine Languages," *Journal of the American Oriental Society*, 36 (1916–17) : 184.

regularity.[10] Aklan *l*, however, has been quite distinctly divided into two phonemes, and with exceptional regularity, so that in general it remains *l* only when preceded or followed by *i* (the Philippine languages, like the Indonesian in general, usually have the vowel phonemes *i*, *a*, *u*) or when in combination with a dental, of which Aklan permits *tl*, *dl*, and *sl* (rare). Otherwise, that is when the entire immediate vocalic environment of the *l* is represented by one or two back vowels (with the *tl*, *dl*, *sl* exception) it becomes a sound best designated phonetically by [γ] (*e* in Aklan orthography and henceforth in this paper). This is the simplest statement of the relationship.[11] Compare:

liog, 'back'	*eamig*, 'cold'
kilok, 'eyelash'	*ngaean*, 'name'
halimunun, 'grass'	*saewae*, 'pants'
kilkil, 'matter on teeth'	*eusong*, 'mortar'
pili, 'choose'	*akean*, 'Aklan'[12]
tatlo, 'three'	
adlau, 'day'	
ginbaslan, 'answered'	

(For the *e*-group compare Tagalog: *lamig*, *ngalan*, *salawal*, *lusong*.[13])

Though the sound [γ] is clearly restricted to back-vowel environment it is rather unusual in nature. It is by no means so clear a spirant as the *g* in North German *sagen*, for example, since the part of the tongue which comes closest to the palate (between hard and soft palate according to my observation, at the hard palate according to Scheerer) is still at considerable remove from the roof of the mouth. But the most important distinction to be made is that the [γ] in pure *a*-vowel environment is different in nature from the [γ] in pure *u*-vowel environment.[14] There is a considerably greater lateral escape of air in words like *saewae* than in words like *sueug* ('rooster'), giving the former type an often very noticeable *l*-quality.

[10] See Dempwolff, *op. cit.*, pp. 117 ff., 226–227.

[11] Putting the variation in this way makes Scheerer's other combinations (of *l* after *m*, *b*, or *p*, or after *ng*, *g*, or *k*, and especially of *li* after *m*, *b*, *p*, *ng*, *k*) unnecessary for the preliminary statement. See Scheerer, *op. cit.*, pp. 248–249.

[12] For other consonant combinations showing *e* for *l* see Scheerer, *op. cit.*, p. 248.

[13] The best Tagalog dictionary is that of P. Serrano Laktaw, *Diccionario Tagalog–Hispano*. Manila, 1914.

[14] Scheerer (*op. cit.*, p. 245) makes a distinction between medial and final position which I have not observed in our informant.

This is, of course, simply a phonetic variant, but it casts some light on the problem of the phonetic origin of the [γ]-sound. It seems fairly clear that, whereas the *i*-vowel and the dentals retained the *l* at its point of contact in the front of the mouth, in other environments the contact was relaxed completely and the tongue point dropped. At that time the consonantal quality of the sound would depend on the amount of spirant friction between the back part of the blade of the tongue and the palate. The origin of the sound may thus account for the much smaller spirant quality of the Aklan [γ] compared to [γ]-sounds having their origin in weakening of [g]-contact. Moreover, this makes the distinction between the [γ] of Aklan *-aea-* and *-ueu-* understandable, since the new position of the back part of the tongue blade was adapted from its original position determined by the vocalic environment. When this part of the tongue was raised slightly to produce the spirant quality of the new sound, the lateral occlusion was complete in *u*-environment but less complete in the "wider" *a*-environment, and some lateral escape of air was maintained, giving the sound the *l*-quality mentioned.[15]

A matter of some importance is involved in the interpretation of this *l–e* relationship. I have the feeling that Scheerer believes the change should be expressed somewhat as follows: *l* in Aklan becomes *e* everywhere except in contact with an *i* or a dental, etc., implying that the trend was to *e* with *l* maintained only in special cases (see his statements in *op. cit.*, p. 247 and *passim*). This is supported by the weight which he attaches to the Bisayan story of the Aklans speaking with a "bound tongue" (*op. cit.*, pp. 250 ff.). It seems to me that Aklan *e* is definitely an original variant of *l* under set phonetic conditions and that the feeling of the original nature of *l* is maintained in certain morphological patterns. Of course, the point made later in this paper that irregularities in the scheme of the *l–e* relationship are in the direction of an *l* where an *e* would be expected, hardly ever toward an *e* for an *l*, might be disallowed because there are no Philippine languages with an *e*-sound which Aklan might borrow (as it borrowed *l*'s in positions normally restricted to *e*). But in the verb system there is a very interesting phenomenon which indicates

[15] Naturally an individual informant makes any phonetic analysis questionable in application to the whole body of speakers of the dialect, but the present interpretation is offered on the basis of repeated investigation of our informant's speech and represents the most careful observation possible under the circumstances.

that *l* is the more stable or "regular" sound in Aklan *Sprachgefühl.* Scheerer[16] demonstrates the influence of the infix *-in-* on verbs with *e* initial. This is shown in such words as: *eubong,* 'bury' — with infix, *linubong,* 'buried'; *eumpat,* 'jump' — with infix, *linumpat,* 'jumped.' Clearly *e* here is definitely unstable enough to be represented by *l* before the infix *-in-*.[17] But Scheerer does not take account of the infix *-um-*, completely parallel in use to *-in-*. Its effect on a *li-* verb shifting to the past tense is illustrated as follows: *liad,* 'sway' — *lumiad; ligid,* 'roll' — *lumigid; ligon,* 'become, make firm' — *lumigon; ligis,* 'run over' — *lumigis;* etc. That is, the *l* is so stable and the "feeling" for it so much more persistent than that for the *e* that, where in precisely similar situations the *e* is replaced by the regular *l, l* is retained even though it is counter to the normal development (see *lumiad,* etc.). I believe that this indicates that *e* has remained, so to speak, secondary to *l.*

The type of change represented by the alternation of *l* and *e* in Aklan is rare. But there is a very interesting parallel in the Batan dialect, spoken on the islands of the Batanes group north of Luzon. Batan, like Aklan, has divided the *l* according to phonetic environment, so that in *i*-environment it becomes *d,* a change very common in Indonesian; in other cases it becomes *x* (at the end of a syllable) or *h* (elsewhere).[18] Thus Batan *d* corresponds to Aklan *l;* Batan *h* and *x,* to Aklan *e.* A comparative table of common words makes the matter clear:

Batan	Aklan	Bisayan	Tagalog	Meaning
dima	*lima*	*lima*	*lima*	five
pidi	*pili*	*pili*	*pili*	choose
tatdo	*tatlo*	*tatlo*	*tatlo*	three
hangit	*eangit*	*langit*	*langit*	sky
buhan	*buean*	*bulan*	*buan*	moon
waho	*waeo*	*walo*	*walo*	eight
aktex[19]	*katue*	*katul*	.....	itch

[16] *Op. cit.,* p. 248.

[17] I am unable to explain why the *i*-prefix (mentioned by Scheerer, *op. cit.,* p. 248) has no effect. See *eumpat, ieumpat mo,* 'jump!' Evidently this prefix, like many others in Aklan, is often felt to be more or less separate from the verb. The varying orthography of Aklan writers supports this theory. See *pagkaeutuk* or *pag ka eutuk.*

[18] See O. Scheerer, "The Batán Dialect as a Member of the Philippine Group of Languages," in *Philippine Ethnological Survey Publications,* 5–6, pp. 23–100. Manila: Bureau of Printing, 1908. See also Conant, *op. cit.,* pp. 191–193.

[19] An example of the frequent Batan metathesis.

It should be remarked that original *l* in Batan covers considerably less phonetic territory in a historical sense than original Aklan *e*. Thus the Batan analogue of 'name,' Aklan *ngaean*, Tagalog *ngalan*, etc. (Dempwolff's *g′*) has no *l* at all but is spelled with an *r*, *ngaran*.

The Aklan system of *l–e* variation is so regular that it is unnecessary to attempt a complete collation. The following list simply presents an extract of twenty-five words from the lexical material for Aklan *l–e*, arranged according to the hypothetical sound (in Dempwolff's notation). Several present the common types of etymological difficulty encountered in treating Aklan and its neighboring languages. Some of these questions are of importance for Indonesian phonology, though they have been given little study. For each of the words the meaning is approximately the same in the three columns. "Hin." ("Hinirayan") and "Hil." ("Hiligainon") indicate dialects of Panay.

	Aklan	Bisayan	Tagalog	Meaning
l initial....	*eusong*	*lusong*	*lusong* [20]	mortar
	eagpit [21]	*lagpit* (Hin.)	*hapit* [22]	squeeze, trap, etc.
		lapit	*lapit*	close
	eamig [23]	*lamig*	*lamig*	cold
	liog	*liog*	*liig*	neck
	lipat [24]	*lipat*	.....	forget
l medial...	*oeo*	*ulo*	*ulo*	head
	paead	*palad*	*palad*	palm
		palaran [25]	*kapalaran*	fortune
	saea [26]	*sala*	*sala*	error, filter
	dila	*dila*	*dila*	tongue
	itlog	*itlog*	*itlog*	egg

[20] Special treatment of the pĕpĕt vowel in Tagalog, which would normally have *i* instead of *u* (see C. E. Conant, *The Pepet Law in Philippine Languages*, p. 936 and *passim*. Chicago, 1913).

[21] **Lapit.* *g* is probably intrusive here. Compare frequent *d*-intrusions referred to on pp. 582–583, note 42.

[22] *Hapit* with *h* for *l*. See pp. 581–582.

[23] This shows an anomalous *i* for the pĕpĕt vowel, regularly *u*.

[24] Dempwolff has **lupa*. The *i* of Bisayan and Tagalog should represent an original *i*.

[25] This change of sound before a suffix or after a prefix is common in both Tagalog and Bisayan (including Aklan). It is interesting to note that these cases do not represent a "return" to medial position, for the secondary medial consonant (from a former final) is different from the original medial. The *Auslaut* of this word is *g′*, which becomes *l*, not *r*, in medial position in both Tagalog and Bisayan. See Dempwolff, *op. cit.*, pp. 122–123.

[26] This word shows the phonemic quality of accent in the Indonesian languages. Accented on the ultima, the word means 'error'; on the penult, 'filter.'

	Aklan	Bisayan	Tagalog	Meaning
l final.....	*bungue*	*bungul*	.....	deaf
	ipil	*ipil*	.....	kind of wood
ḷ initial....	*euwang*	*luwang*	*luwang*	wide
	libo	*libo*	*libo*	thousand
ḷ medial...	*(ma)gueang*	*gulang*	*gulang*	old
	pilak	*pilak*	*pilak*	silver
ḷ final.....	*sampae* [27]	*sampal*	*sampal*	blow on ear or mouth

iḷ No certain Aklan example of *-iḷ* in my lists.

d' medial The *d'* group is full of difficulties. Tagalog is supposed to develop *r*. Bisayan always has *l*.

	uean	*ulan* (Hil.)	*ulan* [28]	rain
	taeum	*talum* *tarum* (Hin.) [29]	*talim* [30]	sharp
	hilao	*hilao*	*hilao*	green
ḍ medial...	*tueu*	*tulo*	*tulo*	drop
	kilay	*kilay*	*kilay*	eyebrow
g' medial...	*ngaean*	*ngalan* *ngaran* (Hin.) [31]	*ngalan*	name
	paeai	*palai* *paray* (Hin.) [31]	*palay*	rice
	ilong	*ilong* *irong* (Hin.) [31]	*ilong*	nose

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[27] The development of an *s* here would seem to indicate that Dempwolff's *t* should be a *t'*.

[28] Dempwolff calls this *l* the result of an original doublet (*op. cit.*, p. 122).

[29] The distinction between Hiniraya and general Bisayan apparent in this group is important. This Hinirayan peculiarity has been noted before but has been treated as a more or less sporadic variation (see J. Kaufmann, *Visaya–English Dictionary* [Ilo-ilo, n. d.], entry "L"). The Hinirayan variant *r* for *l* of Bisayan is not, however, equally distributed among the various *l*-groups. It seems to be generally restricted to *d'*, *ḍ*, and *g'*. For *ḍ* see Hiligainon *bulak*, Hinirayan *burak*, 'bloom'; also *kilay* and *kiray*, 'eyebrow,' and *kolon* and *koron*, 'pot,' for which Kaufmann has no designation of dialect, although they seem to be Hiligainon–Hinirayan variants. For *g'*, besides the words in this table, see Aklan *buea*, Bisayan *bula*, Hinirayan *bura*, 'form'; Aklan *uling*, Hiligainon *uling*, Hinirayan *uring*, 'charcoal.' The *r* of Hiniraya for Bisayan *l* is comparatively rare in the *l*-, *ḷ*-groups, though it would naturally spread analogically.

[30] *Talim* cannot be a Bisayan loan in Tagalog (see Dempwolff, *op. cit.*, p. 129) because of the different vowels arising from pĕpĕt. See also Tagalog *tari*, 'knife or spur on a fighting cock.'

[31] See note 29.

One of the most interesting aspects of the *l–e* problem is the question of those words showing *l* for expected *e* (*e* for *l* occurs only in infixes). These are the ones with which I am acquainted: *gulu*, 'noise' or 'confusion'; *kalan*, 'stove'; *kulong*, 'locked in'; *balai*, 'house.' [32]

The idea which immediately occurs to one is that they represent borrowings. Borrowings on an extensive scale among dialects and languages have hardly received the treatment they deserve as factors in disrupting the "normal" phonological pattern of the Indonesian languages. Here the situation is quite plain, for in addition to each of these words there is a form with the normal Aklan *e*. *Gueu* means 'tangled,' a specialized meaning but clearly related to 'confused.' *Kaeanan* with the locative *–an* means 'eating place.' *Kulong* is more complex. The word in the normal form is semantically a long way off, for *kueong* mean 'curls or locks in the hair.' The field of meaning of *kulong* is pretty clear (see Hinirayan *kurong*, 'chicken coop,' and even Bontoc *kolong*, 'chicken cage'), so that *kueong* is hardly related. In any case, though, there is the phonetically necessary form to explain borrowing with *l* retained, rather than with *Lautsubstitution*.

It is most interesting to note that these words point, not to another Bisayan dialect as source, but to Tagalog (or Bikol). This is certainly germane to the question of Aklan vocabulary. The word *gulo* is not cited in any of the three most reliable and exhaustive dictionaries of Bisayan,[33] but Tagalog *gulo* means 'noise' or 'confusion.' *Kalan* in Bisayan denotes a small tripod for kitchen use, but Tagalog *kalan* means 'stove.' Bikol [34] *kalan* seems to represent a "transitional meaning" — the dictionary defines it as '*un modo de brazero*' or '*hornillo de barro*.' *Kulong* in Tagalog means 'shut in,' 'locked in'; the word is not cited for Hiligainon or Samar-Leyte. The thesis of Tagalog influence on Aklan vocabulary is supported by the general trade connections existing between Aklan territory and

[32] This list excludes the large number of Spanish words like *color*, etc., which keep their *l*. There are, however, a few cases of early *Lautsubstitution*, such as that of Aklan *boesa*, 'pocket,' for Spanish *bolsa* and *bolsilla*. These might have come through Tagalog.

[33] These are: Kaufmann, *op. cit.*; J. F. de la Encarnación, *Diccionario Bisaya–Español*, Third Edition. Manila, 1885; A. Sanchez de la Rosa, *Diccionario Bisaya–Español para las Provincias de Samar y Leyte*, rev. by A. V. Alcazar, Third Edition. Manila, 1914.

[34] See M. de Lisboa, *Vocabulario de la Lengua Bicol*, Second Edition. Manila, 1865.

Tagalog, as well as by the well-known spread of Tagalog influence in the neighboring islands. In some, like Mindoro, the coastal regions are almost entirely occupied by Tagalog-speaking populations.[35] But besides this, Tagalog influence is supported by possible borrowings in many other words.[36]

The only instance in Aklan of anomalous *l* which is definitely a Bisayan loan is the word *balai*, which exists beside regular *baeai*, 'house.' *Balai*, however, is employed only in the form *tagbalai*,[37] a formula of announcement used, for instance, before entering a house or in addressing someone upstairs who is unaware of the speaker's presence. The neighboring dialect of Aklan, Ilayan (usually spoken of as synonymous with Hiligainon), has the common Bisayan form *tagbalai*, which is used in precisely the same situation as the Aklan word. Thus Aklan has taken over unchanged the form of the dialect nearest it. This was completely natural, for *tagbalai* was so specialized semantically that it was felt as a separate word.

A final problem in the *l–e* field — one of considerable importance to Indonesian phonology — should be mentioned. This is the question of initial *h* in the *l*-series. All the cases which I have been able to find with *h* initial instead of *l*, other than the reduplicating forms, present some etymological difficulty besides the *h*. Yet it is hardly doubtful that they belong in the *l*-group. The Aklan examples so far known are: *humuk*, 'soft' (**ləmu*); *huyang*, 'sway' (**layang*); *handung*, 'shade' (**lindung*); *haba*, 'long' (**labu*). All these words have clear correspondences in other dialects which also show *h*. See, for instance, Bisayan *homok* (*lumok*); Bisayan *huyang*, 'unsteady, feeble' (possibly Hinirayan *layang*, 'wide, baggy' [of trousers]); Hiligainon *handong* (Bisayan *landong*); Bisayan *haba* (Hiligainon *laba*).[38] Thus it would seem that the presence of an *h*

[35] See A. B. Meyer, A. Schadenberg, and W. Foy, *Die Mangianenschrift von Mindoro.* Abhandlungen und Berichte des königlichen zoologischen und anthropologisch-ethnographischen Museums zu Dresden, No. 15, map on p. 4. Berlin, 1895.

[36] A fairly clear example in the *l*-series is Aklan *sueung*, 'advance,' Tagalog *sulong*, 'go ahead'; whereas the Bisayan *sulung* means 'pay taxes,' 'shine,' 'defy,' or 'look at.' Bikol influence is possible for Aklan *tuli*, 'wax in ear,' for both Tagalog and Bisayan *tuli* mean 'circumcision.' It is always possible that Aklan, in these words, is the only Bisayan dialect retaining an old meaning.

[37] The *tag–* prefix denotes ownership. In a literal sense *tagbalai* (Bisayan) means 'owner of the house.'

[38] Tagalog forms also show *h* in *haba* and possibly in *huyad*, 'walk with difficulty.' See also Tagalog *hapit*, 'squeeze,' where Aklan has *eagpit*.

in Aklan precludes the possibility of a *e*-form corresponding to the *l* of other Bisayan dialects.

This is true also of the larger and more important group of reduplicating words with *l* initial:

AKLAN	BISAYAN	TAGALOG
eapeap, 'skin'	*laplap*, 'cut on skin'	*laplap*, 'skin'
eobeob, 'hole'	*loblob*, 'ravine,' 'defile'	. . . .
hathat, 'spread'	*hathat*, 'card wool,' 'gin cotton'	*latlat*, 'divulge'
hushus, 'abortion'	*loslos*, 'hernia'	*luslos*, 'hernia'
hayhay, 'hang'	(*hayhay*, 'lie horizontally' ?) *hoyhoy*, 'hang down loosely' *hoyohoy*, 'breeze' *loyloy*, 'droop,' 'hang down'	*laylay*, 'hang loosely' *hayhay*, 'breeze,' 'line of clothes in breeze *halayhay*,[39] 'line or things' or 'breeze
haghag, 'separate'	*laglag*, 'demolish'	*laglag*, 'drop'
hokhok *loklok*[40] } 'eat noisily'	*hokhok*, 'sip,' 'suck noisily' *laklak* *hakhak* } 'eat noisily'	*laklak*, 'eat noisily,' 'gorge'
likdik, 'go out of way to avoid being seen'	*liklik*, 'secret,' 'hidden,' 'do on sly'	*liklik*, 'detour,' 'circuitous route'
lisgis, 'cut'	*lisgis*, 'scratch'	*lislis*, 'cut'[41]

Two striking facts may be noted besides the point made above that *h* in Aklan means that no *e*-form will be found. First, the *h*'s in Bisayan and Tagalog as well as in Aklan occur only before back vowels. There are no forms that I know of where *hi*– occurs in place of *li*– in reduplicating forms in these languages. Second, apparent dissimilation of the second *l* in Aklan words with *li*– has no parallel in the *h*-words.[42] The *h*-forms are hardly a characteristic

[39] A very complex group of words, in which two or more stems may be represented. See also Tagalog *lawlaw*, 'loose.'

[40] Possible confusion of two words in Aklan. *Hokhok* with a meaning like that of the Bisayan *hokhok* may have spread its vowel to the form corresponding to Tagalog and Bisayan *laklak*.

[41] In addition there is an anomalous correspondency: Bisayan *lotlot*, 'squeeze in,' Aklan *dutdut*, 'squeeze in.'

[42] Bisayan *lasgas*, 'strong,' may belong here, but this is apparently not an *h*-word in any dialect. Forms like Aklan *eudgud*, Bisayan *ludgud*, 'scour,' 'rub,'

of Aklan, although there are one or two details peculiar to that dialect. The evidence indicates that they represent a variation of long standing and considerable extent throughout Indonesian territory. Only further lexical evidence can help solve the problem of these anomalous *h*'s.

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are not cited because they are, rather, forms with intrusive *d* in the first syllable. See Aklan *eugud*, Bisayan *lugud*, 'scour.' See also Bisayan *lidgid*, 'shell corn,' but Aklan *ligid*, 'grind corn.' For intrusive *g* compare Aklan *eagpit*, 'trap,' Bisayan *eagpit*, 'spring of trap,' with Tagalog *hapit*, 'squeeze,' 'press,' and *lapit*, 'near,' 'close,' Hiligainon *lapit*, 'near.'

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